TNO-report

96-CMC-R0274   **GES User's Guide version 1.05**

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TNO Building and
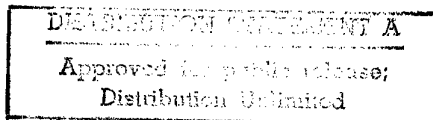Construction Research

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Met het oog op de komst van nieuwe voortstuwingssystemen heeft de Koninklijke Marine behoefte aan een rekenprogramma waarmee verschillende mogelijkheden voor de energieopwekking en voortstuwing van een schip doeltreffend kunnen worden vergeleken met betrekking tot een groot aantal voor de Koninklijke Marine van belang zijnde aspecten.

Dit rapport is de handleiding van het rekenprogramma. Het rekenprogramma heet Geïntegreerde EnergieSystemen, afgekort GES. Met dit programma kunnen verschillende energiesystemen aan elkaar gekoppeld worden. Daarvoor zijn een aantal afspraken gemaakt, hoe een specifiek systeem, in GES apparaat genoemd, opgebouwd moet worden. Gekozen is voor een voorstelling op energiebasis. Door de vermogensuitwisseling van een apparaat naar zijn omgeving uit te drukken als het product van twee variabelen is het mogelijk apparaten gemakkelijk te koppelen. Men kan zich door deze werkwijze concentreren op een apparaat, zonder dat men direct rekening behoeft te houden met andere apparaten in het systeem.

GES rekent stationaire systemen door. Doordat er terugwerking van de omgeving op een apparaat uitgeoefend wordt, kunnen er algebraïsche lussen ontstaan. Dit wordt uiteindelijk wiskundig tot uiting gebracht in een stelsel niet-lineaire vergelijkingen. GES lost dit stelsel iteratief op.

Het programma bevat een bibliotheek waar specifieke apparaten voor de Koninklijke Marine ingebouwd zijn. Tevens bevat deze bibliotheek enkele standaard apparaten waarmee een model opgebouwd kan worden. In de bibliotheek bevindt zich een speciaal apparaat, de *user defined apparatus* waarmee men een eigen apparaat kan schrijven. Het is mogelijk met dit apparaat een eigen-apparatenbibliotheek te bouwen, door deze te verzamelen in een eigen model.

Contents

1 Introduction

GES is a computer program for simulation of various energy systems. GES integrates a powerful library with a 3D-graphical pre- and post processor.

The name GES is an abbreviation of the Dutch 'Geïntegreerde EnergieSystemen'; translated: Integrated Energy Systems. GES is specially written for the Royal Netherlands Navy to calculate energy flows in ships, in the pre-design phase. A special library is incorporated for maritime systems. For general purposes all kind of energy systems can be simulated.

The program GES is written in C++ with object oriented modules. The most important feature of GES is that it is easy to extend. The versions 1.## of GES can only simulate stationary systems. It is possible to write a user defined stationary system library.

If you are a new GES user, you should start by reading 1.2 Overview of GES, page 7. The most important things to learn are how to choose energy directions and how to choose the output gate functions. After you master the basics, you can continue with 1.6 Quick start, page 11 and later by Building a simple model, page 196 in the tutorial chapter in this guide. If you are familiar with building your models by using the import library apparatus, you could start making a user defined model. In the tutorial Example: ideal electric transformer, page 207 you could learn how to make your transformer.

1.1 Purpose of GES

The purpose of the computer program GES is to facilitate, during the pre-design stage of a naval vessel, comparisons of different systems for propulsion and electricity generation, concerning a number of important items:
- energy consumption and efficiency of the ship as a whole;
- pollution through engine emissions;
- heat emissions in air and water (in view of infrared detection);
- dimensions of the installations (in view of required volume);
- weight of the installations.

It should be noted that originally these items also incorporated:
- sound and vibrations on board;
- emissions of sound in air and water.

However, these items could not be simulated with the same model as required for the energy analysis. It was concluded that it was better to analyze these items by means of separate, specific computer programs.

Some typical applications of the program GES are:
- analysis of highly integrated and interdependent propulsion and energy systems on board naval vessels;
- determination of benefits and drawbacks of new types of systems;
- optimization of propulsion and energy systems;

- determination of the residual capacity of a ship in case of malfunctioning of certain installations (which missions can still be performed?).

1.2 Overview of GES

In GES two types of apparatuses are possible: energy apparatuses and signal apparatuses. Energy apparatuses are used for building a model of a physical system. Signal apparatuses are used to control the energy apparatuses.

1.2.1 Energy apparatus

An apparatus in GES has the property that each gate is associated with a (scalar) power flow expressible as a product of two variables. However, in the actual analyses, power needs not to be expressed as a product of two variables. For the class of GES apparatuses it is common practice to split the power into particular factors that can easily be measured and that can be given physical interpretations. In general discussions it is convenient to give the names effort (symbol e) and flow (symbol f) to the two factors and to define the power (symbol P) as follows:

$$P = e \cdot f$$

In principle, these variables can be functions of time, but in the versions 1.## of GES only stationary expressions between the variables are considered.

In Table 1 some common physical variables are listed and it is indicated which variable will be considered to be an effort quantity a which will be taken to be the flow quantity.

Domain	Effort		Flow	
Mechanical translation	Force F	[N]	Velocity V	[m/s]
Mechanical rotation	Torque M	[Nm]	Angular velocity ω	[rad/s]
Hydraulic	Total pressure p	[N/m^2]	Volume flow rate Q	[m^3/s]
Electric	Voltage U	[V]	Current I	[A]
Chemical	Chemical potential μ	[J/mol]	Molar flow $\dot{N}$	[mol/s]
Thermodynamic	Temperature T	[K]	Entropy flow $\dot{S}$	[W/K]
Thermodynamic (stationary)	Specific enthalpy h	[J/kg]	Mass flow $\dot{m}$	[kg/s]

Table 1 Physical effort and flow variables

A number of comments in Table 1 are in order. First, efforts and flows should not consider to be scalar quantities although a vector force F acting on a material point with vector velocity V has an associated scalar power.

If the power flow is split into two variables, the direction of the power flow must still be considered. If two apparatuses are connected, the power flow out of one apparatus is the power flow into the other. The variables are so arranged that, if both effort and flow have the same sign, the energy flow flows into the apparatus. This is as clearly with conventional notations. In the GES notation this is

indicated by a half arrow at the end of the connection line. Figure 1 shows an example of the general model structure of the apparatuses in GES. In principle all apparatuses are identical. They are filled with different functions to describe a physical system. On each gate only one function is possible. This could be an effort function or a flow function. To make a connection it is required that the energy directions of the gates are different, just as the effort and flow functions. GES gives a warning if the user tries to make a connection with wrong conventions.
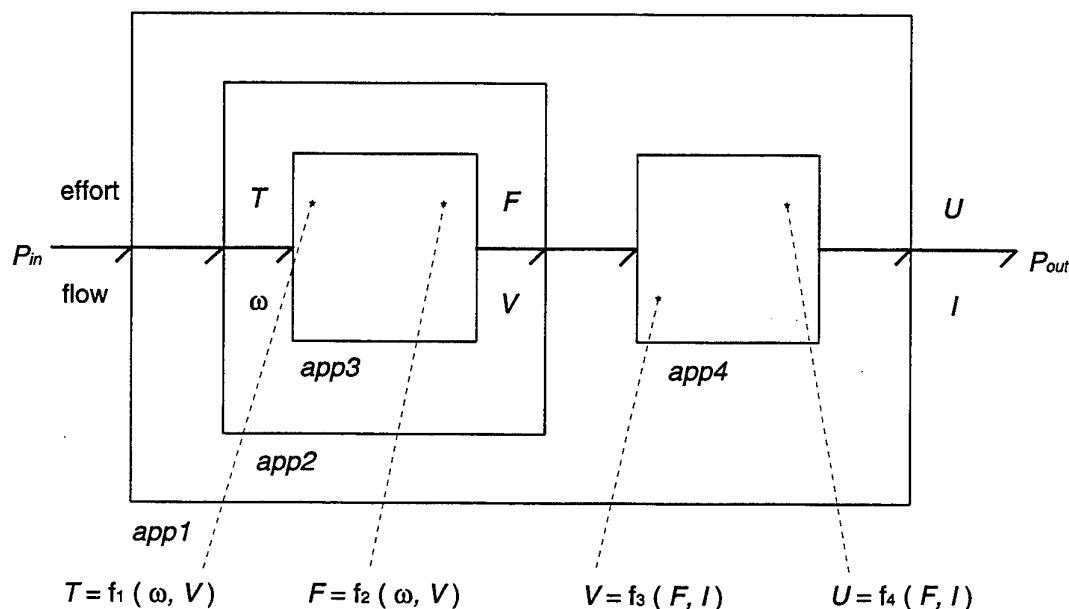
Figure 1   General model structure in GES

The example in Figure 1 contains four energy apparatuses: *app1*, *app2*, *app3* and *app4*. In *app1* two apparatuses are defined: *app2* and *app4*. In *app2* is one apparatus: *app3*. The last apparatus in the path contains the effort and flow functions. Apparatuses covering one ore more other apparatuses are called in GES *mantle apparatuses*. This example contains two mantle apparatuses: *app1* and *app2*. Apparatus *app2* and *app4* are connected. Apparatus *app2* calculates the effort F with function f_2 and apparatus *app4* calculates the flow V with function f_3.

In GES the effort text is written in red above the half arrow and the flow text is written in green under the half arrow. If the variable is a function then the text is written to the end of the half arrow. If the variable is an argument then the text is written near the apparatus. For the *user defined apparatuses* it could be that there is no function defined. In that case a black zero is written to the end of the arrow.

The import library apparatuses have all the effort and flow functions default in memory. With the *user defined apparatus* it is possible to make these functions oneself.

Trough this structure in GES it is possible to insert new apparatuses or even complete model structures.

GES sorts the functions before they are calculated. The results could be a collection of implicit functions and/or a set of explicit functions. See also Solution principles, page 164.

GES tries to calculate every function if a calculation is possible. Therefore more than one model can be calculated in one run.

1.2.2 Signal apparatus

In GES most signal apparatuses have one gate. The energy variable flow is used as a signal function value. The signal apparatuses have a priority in running. The pre-types are running before the energy apparatuses and the pro-types are running after the energy calculations. Some signal import apparatuses have a special priority to run, they are sorted automatically by GES.

If a signal apparatus is connected to an other apparatus the visible connection is made in the origin of the apparatus or on the connected gate of the apparatus. For instance the *epi apparatus* in Figure 2. The *epi apparatus* is connected at the Diesel in the (local) origin of its figure.
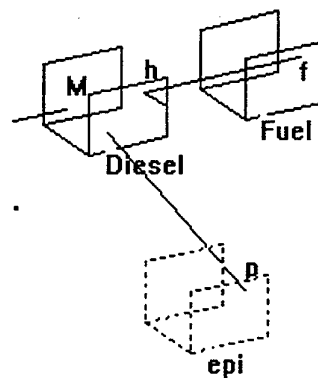
Figure 2   Example connection of signal apparatus

1.2.3 Apparatus structure

In GES all apparatuses have an identical object structure. For every apparatus is chosen:
- the number of gates.
- the number of parameters
- the effort or flow function of a gate
- a local workspace
- a parser string (this is a text string for the equations).

The number of gates is depending on the energy interaction with the surroundings. The number of parameters is depending of the apparatus type. The effort and flow functions of a gate are depending on the available function who must describe the variable. It is possible that both effort and flow functions could be expressed. In that case more apparatus descriptions are possible.

In the local workspace some variables can be set. These variables are visible for the user in the results mode. In the parser string some special functions (parser functions) can be set to perform operations

with the workspaces and the parameters of the apparatus. The parser string is specially used by the *user defined apparatus*, but it is possible that the user uses the parser string for comments (e.g. for import library apparatuses) and startup low-level initialization calculations.

In GES two special global workspaces are available: the system workspace and the global workspace. All apparatuses in the model can use these workspaces. With the global workspace it is possible to exchange variables with other apparatuses which are not connected in one model. Global workspace variables are marked with an exclamation mark (for instance: !A).

With the system workspace the user can also exchange values with separated models which are created with **New**. The system workspace gives information about the calculation errors and calculation flow in special reserved variables. The system workspace variables are marked with two exclamation marks (for instance: **!!error**).

1.3 System requirements

GES requires:
- MS-DOS® version 5.1 or later;
- Microsoft® Windows™ version 3.1, support for 386 enhanced mode and WIN32 applications;
- Windows 95 (some called Windows 4.0);
- a personal computer with the Intel 80486 or Pentium processor and 4 megabytes or more of
  memory;
-          an 80387 math coprocessor (of coprocessor intern by the other processors);
-          a hard disk with 8 megabytes of free disk space;
-          a monitor that is supported by Windows;
-          a mouse that is supported by Windows, recommended is to define a doubly click button;
-          a printer that is supported by Windows.

1.4 GES directory structure

GES is distributed in compressed format on a diskette. The installation procedure moves the files on this disk to the hard disk, decompresses them, and installs them in the Windows environment. After installation, the GES directory will posses the following files and subdirectories.

\GES	The GES binary and associated files
\GES\DATA	The data work directory
\GES\EXAMPLES	The example model directory
\GES\MODEL	The default user model directory

1.5 Installation instructions

See the GES installation Disk.

1.5.1 Windows 3.11

After installation the user can set the program GES in a program group. First, select the group (e.g., Applications), then you must select the **New** option of the **File** menu. Choose Program Item and click on **OK**. The **Program Item Properties** dialog box must contain:
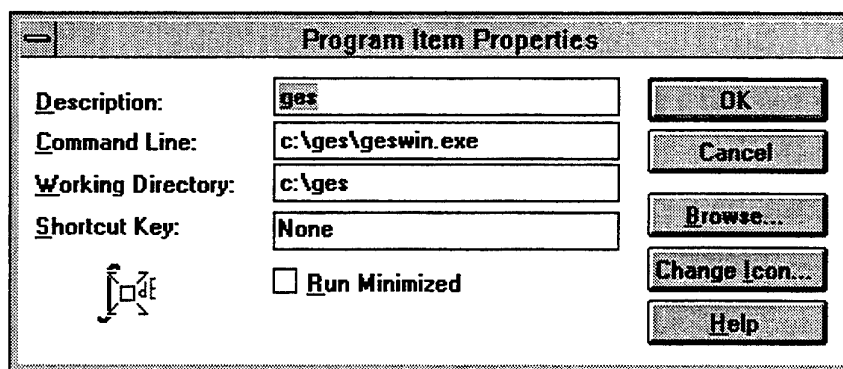
If you click on **Change Icon** the internal icon of GES is displayed.
The GES icon is:

1.5.2 Windows 95

Create a short cut by clicking on the right mouse button in the desktop area. Click on New and select Shortcut. Browse to the GES program executable GESWIN.EXE and finish the procedure.

1.6 Quick start

If you would like to start GES quickly, this section describes a short series of actions you can take to get going.

1. Start up GES in Windows by double-clicking the icon GES or run GESWIN.EXE in the GES directory. The last model could appear if this is set into the GES.INI file.

2. Select **New** in de pop-up menu **File**. A new GES window will appear.

3. Select **Benchmark** in de pop-up menu **Simulation**. A simulation model of a propulsion installation will appear.

4. By clicking on **Start** in de pop-up menu **Simulation** you can start a simulation by **Run**.

5. If you click on **Result mode** under the header menu **Simulation** the cursor is set in the **results mode**. If you click on a gate of an apparatus the results of that particular chosen apparatus are displayed in a dialog box.

6.   You can adjust the parameters of your model by selecting **Parameters values** from the **Edit**
        menu. With the mouse cursor you select the apparatus.

7.   In section 2.1 Object manipulation, page 15 more features are explained for manipulation of
        the model.

1.7 What is new in GES version 1.05

This section summarizes the changes and enhancements that have been incorporated into GES
version 1.05 with respect to the previous version 1.04. The most important changes are:

System workspace
        The global workspace is coupled to the highest apparatus in the apparatus tree. This is the
        mantle apparatus of the new window. In GES it is possible to open more than one new
        models. In version 1.05 it is no longer possible to exchange values with the global workspace,
        because every model has its own global workspace. For changing values between new models
        the user can use the system workspace.

Failure module
        A failure module is developed to calculate the probability of failing of the installation or a
        part. The user can use more than one failure module and define his own probability variable.
        The method is based on the 'fault tree analysis'. An apparatus with one input gate is present
        as an AND function and an apparatus with more than one input gate is present as an OR
        function. Apparatuses inside an apparatus are present as an OR function.

Log file
        A log file can be used for information of the GES program. This file is closed after the GES
        program is stopped.

Initialization file
        An initialization file (GES.INI) can be used to set up the system variables of the GES
        program. The user can define his own environment by changing the settings under the section
        names. There are eight sections names: [window], [directories], [files], [programs], [tools],
        [iterations], [plotlayout], [timevalues]. Each section has his own settings. See Appendix A
        Initialization file GES.INI, page 211.

1.7.1 System workspace

In GES version 1.05 the system workspace is introduced. The system workspace is used for error reporting and calculation flow reporting to the user. Experienced GES users can optimize the *user apparatus* by using the default system workspace variables:

- !!error
  This variable is used to give the user information if there is an error encountered in the calculation process.
- !!step
  This variable is used to give the user information of the actual process step. The first step value is 0 and the last step value is (!!nr_steps-1).
- !!nr_steps
  This variable is the total number of steps in the calculation process (foreground).
- !!flag
  This variable gives the user information about the state of the calculation process. The flag values are:
  0 : pre-calculation
  1 : parameter iteration
  2 : parameter iteration and normal iteration
  3 : normal iteration
  4 : normal calculation or initialization calculation (for time version of GES)
  5 : time calculation (for time version of GES)

It is possible to define your own global workspace variables.

1.7.2 Error message

If there is a calculation error encountered, the global system variable !!error is set to 1 and the calculation process is stopped. The error message is written in the list box of the start simulation dialog box. The error message is also written in the log file. The user can set the system error variable with the *user defined apparatus*, however the calculation process is not stopped.
If a foreground calculation process is started the error variable is set to 0. This holds for every step. By a background calculation process the error variable is also set to 0.

1.7.3 Warnings

Most warnings in GES are given by the parser for the user defined apparatuses. A warning does not stop the calculation process but there could be wrong results. The warnings are written in the log file of GES.

1.7.4 Initialization file

GES uses for start-up the initialization file GES.INI. See Appendix A

Initialization file GES.INI, page 211 for the description.

1.7.5 Log file

The log-file gives information about GES after the program is closed. Maximum 9 log-files can be used for history purposes. In the GES.INI file under section name [files] you can set the number of log files behind logfilenrs= and the log name behind log=.

```
[files]
logfilenrs=0
log=C:\Ges\ges.log
```

In the log-file is set:
*   The time of starting the GES program.
*   The opening model file with the name of the GES version.
*   The apparatuses which are calculated
*   The iteration error.
*   The last calculated apparatus if there is an error.

A typical log-file is:

```
Program GES Running from time: Wed Oct 08 16:05:45 1997


open file: C:\Ges\MODEL\Asyaand.mod  GES version:  1.05
calculation apparatus: asynchrone aandrijf
open file: C:\Ges\MODEL\Hyd.mod  GES version:     1.05
calculation apparatus: asynchrone aandrijf
calculation apparatus: asynchrone aandrijf
iteration error: par-functions != set-functions
last calculated apparatus: diesel ,gatenr: 1
```

2 Graphical interface

The GES graphics system provides a variety of tools to manipulate the models. The representations of the models are in 3D. Results of the calculations with more than one step can be presented in 2D-plots. Therefore a special window is available. See 2.3.6.4 Set Plot window (Simulation menu), page 45.
This section describes the menu functions implemented for the GES Window.

2.1 Object manipulation

2.1.1 Cursor modes

The mode of the cursor depends on the requested action in the **Edit** menu or **Options** menu. There is no real cursor shape or message to show the active mode. In the **Options** menu a check mark indicates the last cursor mode. A option not in use is grayed.

The cursor modes are:
- Select (default)
- Parameter values (set in **Edit** menu)
- Equations (set in **Edit** menu)
- Gate energy (set in **Edit** menu)
- Connect (set in **Options** menu)
- Disconnect(set in **Options** menu)
- Disconnect (set in **Options** menu)
- Mantle (set in **Options** menu)
- Dismantle (set in **Options** menu)
- Parameter setup (**Simulation** menu)
- Results mode (**Simulation** menu)

The cursor is set in the default select mode by clicking in the free space.

2.1.2 Select apparatus

To select an apparatus, click on one of the gates. This may be the beginning or the end of the gate vector. If the selection succeeds, the selected apparatus is written with a dot line. You deselect the apparatus by clicking in the free space (not a gate vector). The name of the selected apparatus is written in the status bar.

2.1.3 View of the model

- By pressing on the **Home** key the model is drawn in perspective. This is the default drawing mode.
- With the **left** and **right** arrow keys you can move the model horizontally and with the **up** and **down** arrow keys you can move the model vertically.
- If you press on the **F7** key the model is projected in the y-z area; x-axis points out of the screen.
- If you press on the **F8** key the model is projected in the x-z area; y-axis points out of the screen.
- If you press on the **F9** key the model is projected in the x-y area; z-axis points out of the screen.
- If you press on the **INS** key the model is zoomed out.
- If you press on the **SPACE** bar the model is zoomed in.

Using the mouse:
- If the **F1** key is hold down, the model is moved with the mouse cursor.
- If the **F2** key is hold down, the model is zoomed out if you move the mouse down. The model is zoomed in by moving the mouse up.
- If the **F4** key is hold down and the mouse is moved down the model is rotated positive around the **x**-axis.
- If the **F5** key is hold down and the mouse is moved down the model is rotated positive around the **y**-axis.
- If the **F6** key is hold down and the mouse is moved down the model is rotated positive around the **z**-axis.

2.1.4 Move and copy the apparatus

An apparatus can be moved and or copied by using the mouse. If you select an apparatus and hold down the left mouse button you can drag the apparatus to an other location. If you choose an other projection (press the F7, F8, F9 key) you can drag the apparatus in an area (y-z, x-z, x-y).
If the original position of the apparatus and the target location are within the same window, the apparatus is moved. Any lines connected to the moved apparatus are redrawn.
If you drag an apparatus in a different window, the apparatus is copied. A copied apparatus is a free apparatus and does not have connections to other apparatuses. All apparatuses inside the apparatus are also copied.
If you move an apparatus in the same window and you press the <Ctrl> key the apparatus is copied. A selected apparatus is also copied if you click on copy in the Options menu.

2.2 GES MDI window

The GES window has a Multiple-Document Interface, or MDI, for managing multiple windows or views associated with a single application. Within the MDI client window GES windows are displaying the model structure. You can control the GES windows with menus in the MDI client window. If you start GES and no model is present a typical menu structure is:
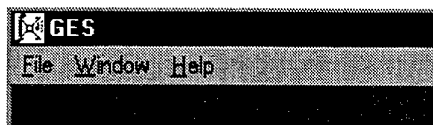
The **File** menu contains items to open a new model structure or to exit the program.
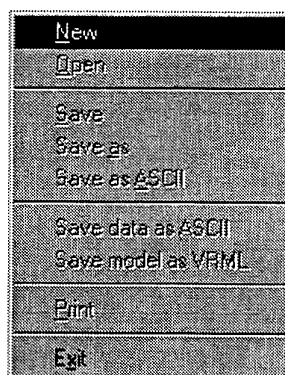
The **Window** menu contains disabled items to arrange the GES windows. The functions are automatically enabled if they are useful.

The Help menu contains items to help the user.

Index   The help index is not implemented.

About   About GES shows information about
               the program GES and the system.

About displays the following information window:
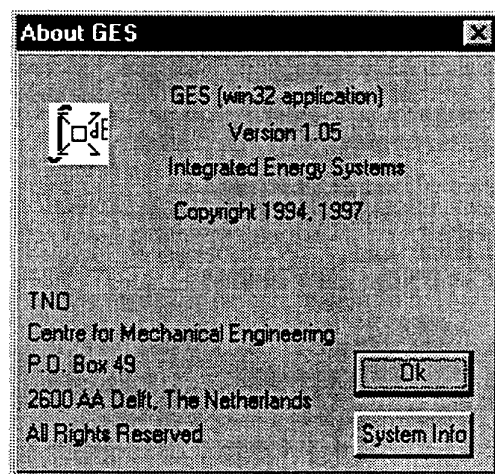
The following system information is displayed:
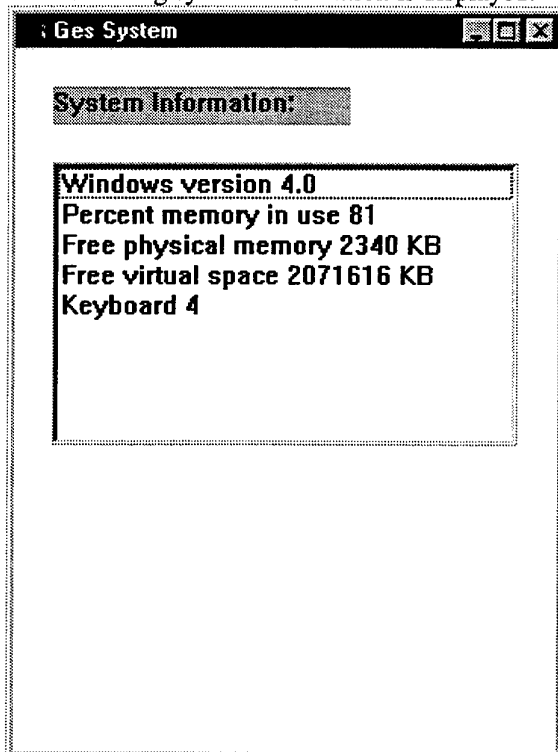
- The Windows version (4.0 is Windows 95).
- Percent memory in use. Present a number between 0 and 100 showing current memory utilization, in which 0 indicates no memory use and 100 indicates full memory use.
- Free physical memory. Indicates the number of bytes of physical memory.
- Free virtual space. Indicates the number of bytes of unreserved and uncommitted memory in the user mode portion of the virtual address space of the calling process.
- Keyboard number.

2.3 GES menus

The GES Windows menus are shown below.
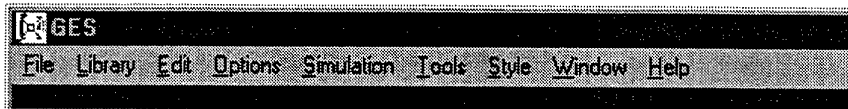
- The **File** menu contains items to open and save model structures.
- The **Library** menu contains entries to sub-libraries. In this guide this library is named the import library.
- The **Edit** menu items allow to apply editing functions to apparatuses.
- The **Options** menu allows building a model.
- The **Simulation** menu allows to start the simulations and to analyze the results.
- The **Tools** menu contains entries to start other programs.
- The **Style** menu items allow to update the figures.
- The **Window** items allow to arrange the windows.
- The **Help** menu shows information about the program GES.

2.3.1 File menu
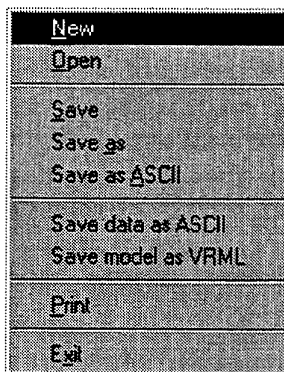
- **New** creates a new system.
- **Open** selects a model to load from disk.
- **Save** writes the model to file, using the same file name.
- **Save as** writes a model to a new file.
- **Save as ASCII** writes a model to an ASCII file.
- **Save data as ASCII** writes result's data to an ASCII file.
- **Save model as VRML** writes model as VRML file. This is not correct implemented.
- **Print** prints the contents of the window on the current printer.
- **Exit** stopped program GES.

2.3.1.1 New (File menu)
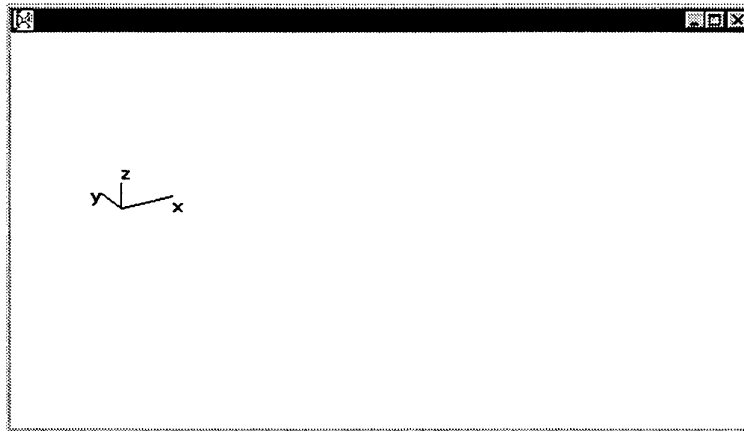
New opens a new window called "New" in which you can create a new system. You use this command if you want to separate models. By opening "New" is empty. The first apparatus you create is the mantle apparatus of your new model. The mantle apparatus is not visible. Your mantle apparatus is as the border of the model. The name of the mantle apparatus is set in the window caption. All the following created apparatuses are incorporated in the first created apparatus.
In the original of the coordinate system an arrow shows the orientation of the coordinate system. In the GES.INI file you can set the world coordinates.

2.3.1.2 Open (File menu)
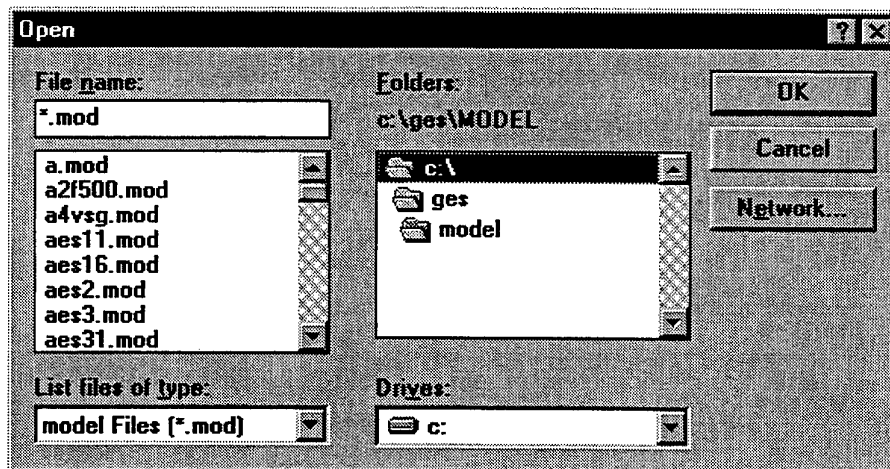
Open displays a dialog box with a list of existing files from which you can select the file you want to insert in the system. You can list the contents of a different directory by changing the path in the drop list **Folders**. You can view more file names by moving the horizontal scrollbar up or down. You can select a file by double-clicking on the name or by clicking on the file name and then clicking on the **Open** button. The default file type has the extension .mod. You can use other extensions.

2.3.1.3 Save (File menu)
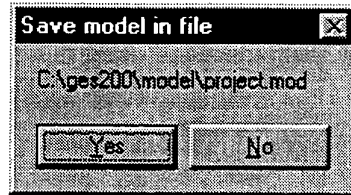
Save displays a dialog box with the name of the already opened file of the model. If the existing model is not opened from a file, the **Save as** dialog box is displayed. By clicking on the **Yes** button (or Enter key) you can save the model in its current name.

2.3.1.4 Save as (File menu)
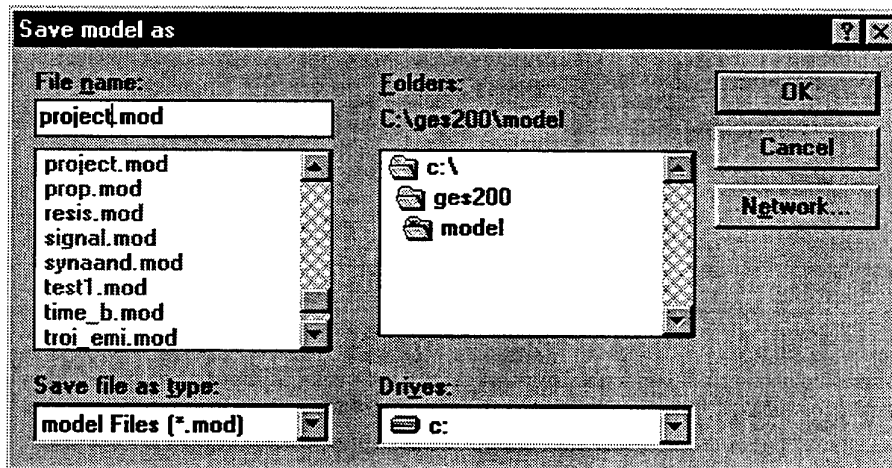
Save as displays a dialog box in which you specify the name of the file in which to save the contents of the model. You can save it to its current name or enter a new name. You can also change the directory in which it is to be saved. When **Save** is chosen for an import library built model, the **Save as** dialog box is also used.

2.3.1.5 Save as ASCII (File menu)

You can save your model in ASCII format. This item is not worked out. It is not possible to read this format. This option is for future applications.

2.3.1.6 Save data as ASCII (File menu)
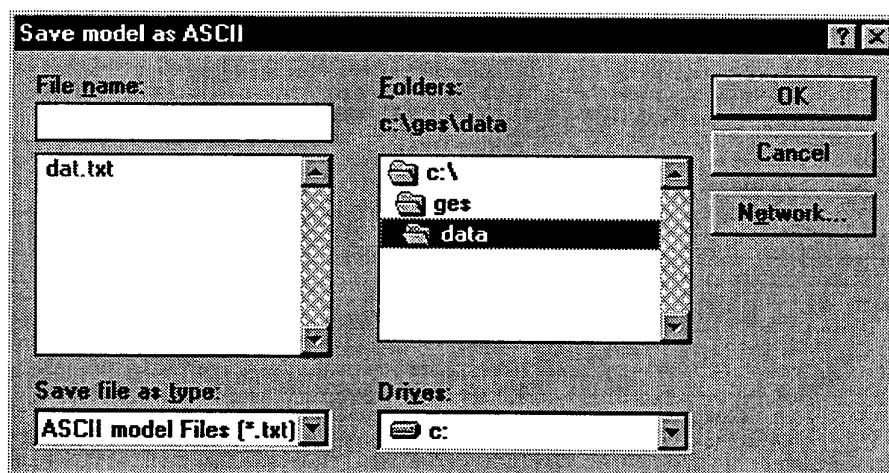
Save data as ASCII displays the **Save as** dialog box with files with extension *.txt* of the \ges\data directory. By clicking on the **Save** button the calculated data of all apparatuses are saved in an ASCII file *dat.txt*.

The data file has the following structure:

"name"	the name of the apparatus between quotation marks
"# gates " value	text *# gates* between semicolons. value is the total number of gates
" gate " value	text *gate* between semicolons. value is the gate number
" e" value [-]	effort name between semicolons (e is default), effort value, unit symbol ([-] is default)
" f" value [-]	flow name between semicolons (f is default), effort value, unit symbol ([-] is default)
" power" value [W]	power between semicolons (power is default), value, unit symbol ([W] is default)
" dissipation" value [-]	dissipation between semicolons, value, unit symbol ([-] is default)
" efficiency" value [-]	efficiency between semicolons, value, unit symbol
	empty line
"name next"	next apparatus results between quotation marks

Example: Propulsion apparatus with two apparatuses name Resis. and
Trans.:

```
"Propulsion installation"
"# gates "                                  2
" gate "                                    0
"                            e"   0.000e+00           [-]
"                            f"   0.000e+00           [-]
"                        power"   0.000e+00           [-]
" gate "                                    1
"                            e"   0.000e+00           [-]
"                            f"   0.000e+00           [-]
"                        power"   0.000e+00           [-]
"                  dissipation"   0.000e+00           [W]
"                   efficiency"   0.000e+00           [-]


"Resis."
"# gates "                                  1
" gate "                                    0
"                            F"   0.000e+00           [-]
"                           vs"   0.000e+00           [-]
"                        power"   0.000e+00           [-]
"                  dissipation"   0.000e+00           [W]
"                   efficiency"   0.000e+00           [-]


"Trans."
"# gates "                                  2
" gate "                                    0
"                           mo"   0.000e+00           [-]
"                           wo"   0.000e+00           [-]
"                        power"   0.000e+00           [-]
" gate "                                    1
"                           mi"   0.000e+00           [-]
"                           wi"   0.000e+00           [-]
"                        power"   0.000e+00           [-]
"                  dissipation"   0.000e+00           [W]
"                   efficiency"   0.000e+00           [-]
```

2.3.1.7 Print (File menu)
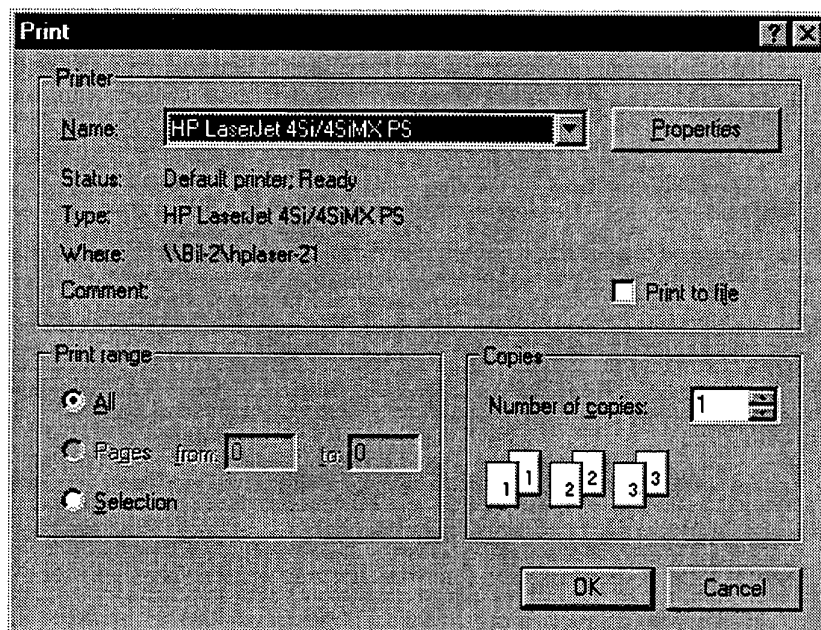
Print displays a dialog box of the installed printer. By clicking on the drop down box you can change the printer. If you want to print your graphical model you must click on the **OK** button.
See for changing the print size 2.4.1 Plot layout, page 54.
If you click on **Properties** you can change the printer settings.

2.3.2 Using the Windows Clipboard

You can move information between GES and other applications using the Windows Clipboard. To transfer a plot of a Window application to another application, use the Windows key sequence **ALT-Print Screen** to copy information to the Clipboard from the active window. Then, invoke the other application (or make the other application's window the active window), and select the **Paste** command from it's **Edit** menu to past the contents of the Clipboard to the active window.

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2.3.3 Library menu
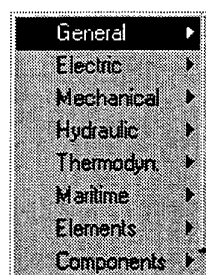
- **General** is a sub-library to general apparatuses.
- **Electric** is a sub-library to electric apparatuses.
- **Mechanical** is a sub-library to mechanical apparatuses.
- **Hydraulic** is a sub-library to hydraulic apparatuses.
- **Thermodyn.** is a sub-library to thermodynamic apparatuses.
- **Maritime** is a sub-library to maritime apparatuses.
- **Elements** is a sub-library to element apparatuses.
- **Components** is a sub-library to ideal apparatuses.

2.3.4 Edit menu
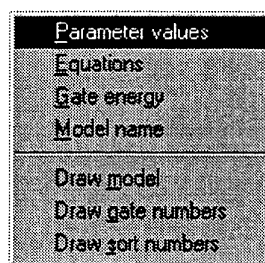
- **Parameter values** is a cursor mode to change parameter values.
- **Equations** is a cursor mode to change equations in the parser string.
- **Gate energy** is a cursor mode to change gate properties.
- **Model name** is an item to change the name of your active window or your selected apparatus.
- **Draw model** resets your drawing.
- **Draw gate numbers** sets the gate numbers in the model.
- **Draw sort numbers** sets the sort numbers in the model

2.3.4.1 Edit parameter values (Edit menu)

Sets the cursor in the **Parameter values** mode. If you click on an apparatus gate the following dialog box is displayed. The last ten parameters are showed.
As an example the *diesel_exhaust apparatus* is chosen.

Index	Name	Value	Unit
0	Actual speed	188	[rad/s]
1	Nominal speed	1000	[c/min]
2	Min speed limit	400	[c/min]
3	Nominal power	1200	[kW]
4	C in fuel	86	[%]
5	H2 in fuel	13	[%]
6	S in fuel	1	[%]
7	Aspect values	matrix[4][8]	[-]
8	Calculation values	matrix[11][1]	[-]

Parameter values: diesel exhaust

[Up] [Add Par] [Read file] [Write file] [Plot mat] [OK] [Cancel]
[Down]

Index is the serial number of the parameter in the apparatus. The first parameter starts with number 0. The parameter can be a value or a matrix. Every parameter has a name. You can change the name in the text box **Name**. The parameter value must be placed in the text box field **Value**. This value can be a number (for instance: 188) or a global variable (for instance: !speed). The unit of the parameter must be set in the **Unit** text box. You can change all values and names. If you click on the **OK** button these values are loaded into the apparatus and the dialog box is closed. If you click on **Cancel** only the dialog box is closed.

Up and **Down** button
With the **Up** button you can scroll the parameters up, and with the **Down** button you can scroll the parameters down. This is very useful if you have more than ten parameters in the apparatus.

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Plot mat button

If there is a matrix parameter you can plot it if you click on the **Plot mat** button. In the **Value** text box the matrix is expressed with its dimensions (for instance matrix[4][8]). If there are more matrices you can select the right one by clicking in the text box **Value**, and than plot it by clicking on **Plot mat**. The following dialog box is displayed:

The dialog box displays a part of a matrix. The element index starts with [0][0]. In the upper left text box matrix element [m][n] is displayed.

m and **n** buttons

You can scroll through the matrix by changing the values in the text boxes **<m>** and **<n>**. To accept these values you must click on the **m** or **n** button. With the < and > buttons you can click one step through the matrix.

If you click on the **OK** button the new values are accepted and the matrix box is closed. If you click on the **Cancel** button only the matrix box is closed.

Read file button

It is possible to read parameter values from a text file. If you click on the **Read file** button the following dialog box is displayed:

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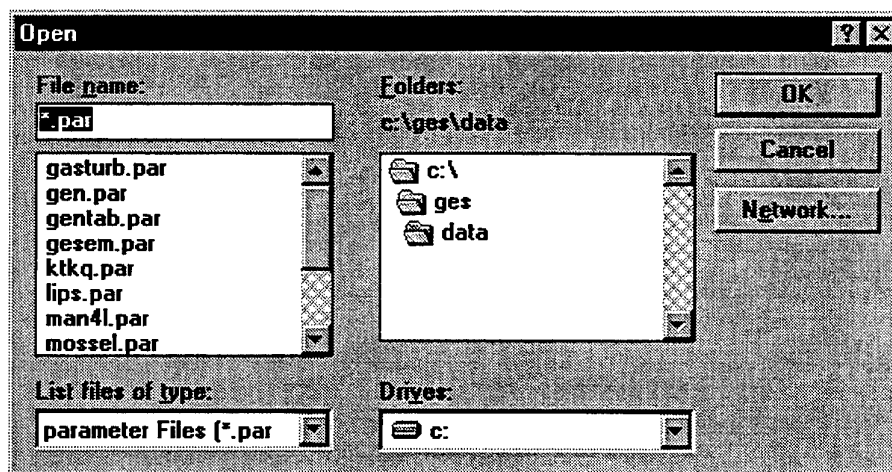
The default directory is *ges\data* and the default extension of the file is **.par**. If you read from a file the file must have the correct format. It is possible to read the first parameters into the apparatus. The format of the parameter structure is described in the following section (**Write file**).

Write file button

If you click in the parameter dialog box on the **Write file** button, the following dialog box is displayed:
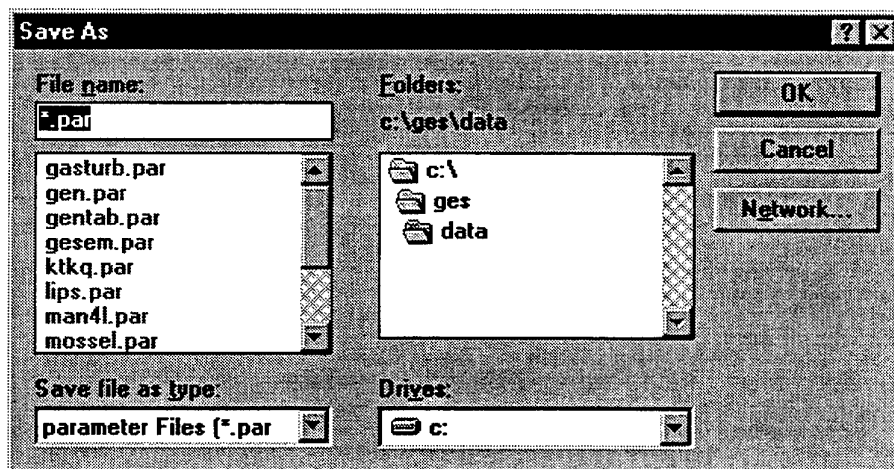
You can type your own file name or choose a file for overwriting.

An example of a parameter file is:

```
diesel sw28pr
number of parameters: 8
    0 Variable speed                       100 [rad/s]
    1 Normal speed                        1000 [c/min]
    2 Min speed limit                      350 [c/min]
    3 Nominale power                      3640 [kW]
    4 % C in fuel                         86.9 [-]
    5 % H2 in fuel                          13 [-]
    6 % S in fuel                         0.1 [-]
    7 Aspect values              matrix m:   4 n:    8 [-]
  766.220000    1.000000    8.619119    1.348148    0.010719   -0.026816    0.107278    2.000000
   42.300000    1.000000   -1.153626    0.651860   12.971739  -23.458330   12.493682    0.000000
    3.090000    1.000000   -0.885492    0.261925    5.435819  -14.169077   11.389777    0.000000
    2.760000    1.000000   -1.328410    0.577838   24.875213  -59.065051   38.199015    0.000000
```

- on the fist line the name of the apparatus is displayed;
- on the second line the text number of parameters is displayed: followed by a number;
- then the parameter fields are displayed.

The index number is 3 characters in width, the parameter name 30 characters in width, the value 10 characters width and the unit type 10 characters in width.
If a parameter is a matrix, the matrix is followed on the next lines. The element value width is 11 characters.

Add par button
If you click on the **Add par** button you can add a parameter into an apparatus. The following dialog box is displayed.
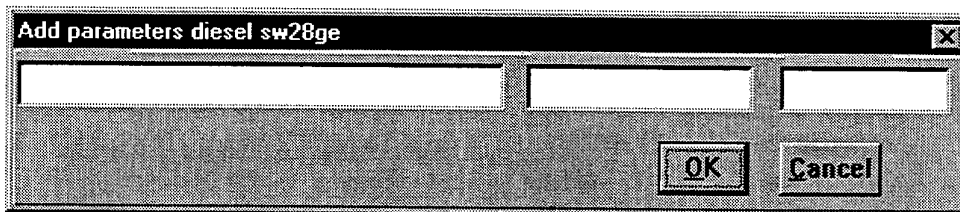
It is possible to set the name, value and unit of the new apparatus. If you click on the **OK** button the new parameter is appended and this dialog box is closed. If you click on the **Cancel** button only the dialog box is closed. It is **not** possible to set a global variable into the **Value** text box. You can do that later in the **Value** text box of the **Parameter values** dialog box.
If you want to add a **matrix** parameter you must first add a normal parameter. With the **Edit equations** menu you start the parser of GES by clicking on the **Equations** button. Than you must insert the INIT_MATRIX function into the parser string of the apparatus. The parser of GES executes this function.

2.3.4.2 Edit equations (Edit menu)

Sets the cursor in the **Edit equations** mode. If you click on an apparatus gate the following dialog box is displayed. As an example a fictive user apparatus (named *Hull_Prop_Rot*) is chosen.
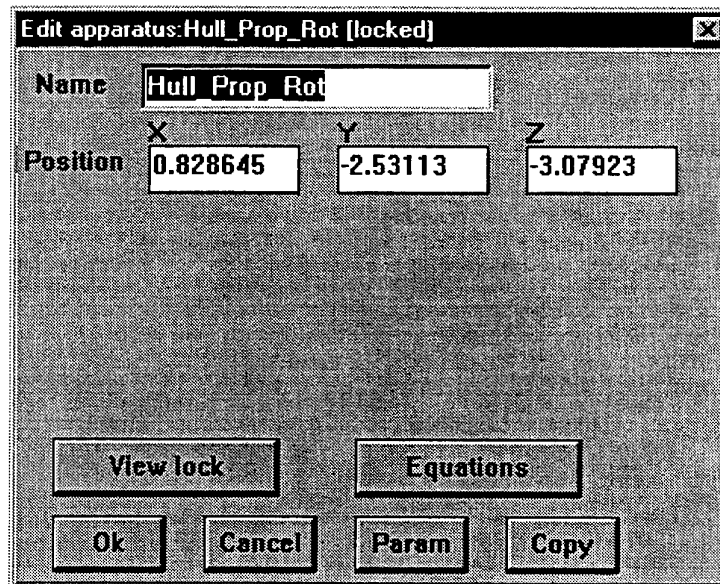
In the first text box you can change the user name.

There are three text boxes **X**,**Y** and **Z** to define the actual position of the apparatus. You can change a position value by fist clicking into the text box.

If you click on the **OK** button the changes are set into the apparatus and the dialog box is closed. If you click on the **Cancel** button only the dialog box is closed.

By clicking on the **Param** button the parameter list of the apparatus is displayed. This is the same dialog box as described in 2.3.4.1 Edit parameter values (Edit menu), page 28.

A **View lock** button is shown if the apparatus is locked. This means that this apparatus has apparatuses inside and are locked. You can not see them directly by double clicking. By clicking on this button a GES window is opened with the apparatuses inside.

By clicking on the **Copy** button the apparatus is copied into the model. The following message is given:

The message box is closed by clicking on the **OK** button. The apparatus is showed on top of the old apparatus. It is possible to copy more than one apparatus.

If you click on the **Equations** button the internal parser string of the apparatus is copied into the file *default.equ* and the following dialog is displayed.
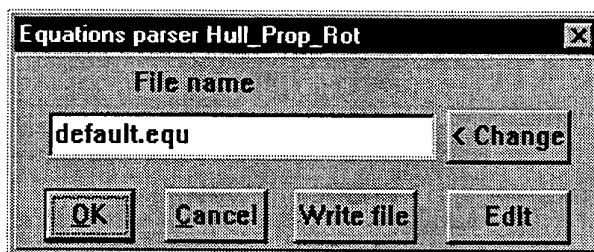
If you click on the **OK** button the equation file in the text box **File name** is read into the internal parser string of the apparatus. The equations dialog box is closed and the parser in GES compiles the string. Possible errors are displayed in a message dialog box. If you click on the **Cancel** button only the dialog box is closed.

You can change the equation file by typing a new name into the **File name** text box or you can choose a file from your own directory.

If you click on **Change** a dialog is displayed with some listings to choose an equation file.

2.3.4.3 Edit gate energy (Edit menu)

Sets the cursor in the **Edit gate energy** mode. If you click on an apparatus gate the following dialog box is displayed. As an example the *diesel apparatus* is chosen.
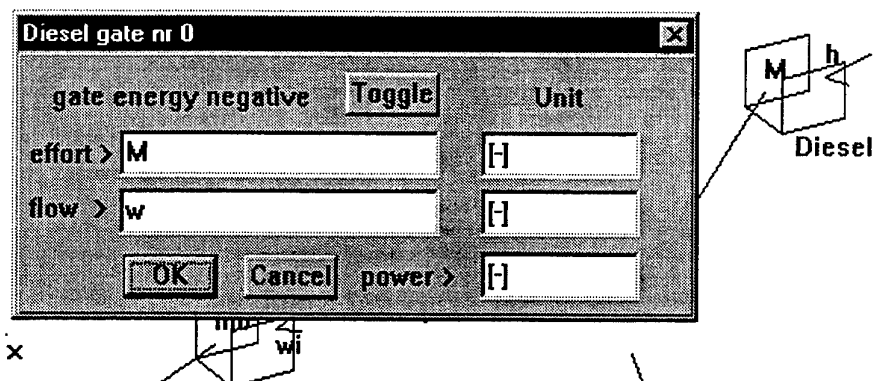
In the caption of the dialog box the name of the apparatus and the chosen gate number are displayed. The sign of the energy flow (gate energy negative) is displayed in the box. With the **Toggle** button you can change the sign of the energy flow. If the gate is connected to another apparatus the toggle does not work. Be careful with changing the energy flows of the gates because not all gate equations of the apparatuses take into account the sign of the energy flow.

In the **effort** text box you can change the name of the effort. The default effort text is for most apparatuses an **e**. Next to the **effort** text box is the **Unit** text box to change the unit of the effort. In the **flow** text box you can change the name of the flow. The default flow text is for most apparatuses an **f**. Next to the **flow** text box is the **Unit** text box to change the unit of the flow. In the **power** text box you can change the power unit of the gate.

If you click on **OK** the values are set into the apparatus and the dialog box is closed. If you clink on the **Cancel** button only the dialog box is closed.

You can open more **Edit gate energy** dialog boxes by clicking on another gate. The next dialog box is displayed on top of the other. You can drag them apart.

2.3.4.4 Draw model (Edit menu)

If you click into this menu you can redraw the model.

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2.3.4.5 Draw gate numbers (Edit menu)

If you click into this menu the gate numbers of the apparatuses are written in the model. See the following example.
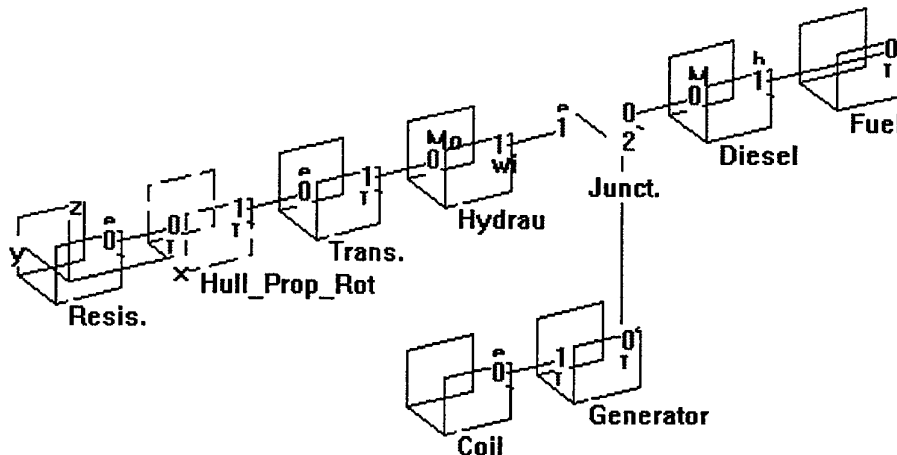
The gate numbers disappear by redrawing the model.

2.3.4.6 Draw sort numbers (Edit menu)

If you click into this menu the sort numbers of the effort and flow functions are written in the model. See the following example.
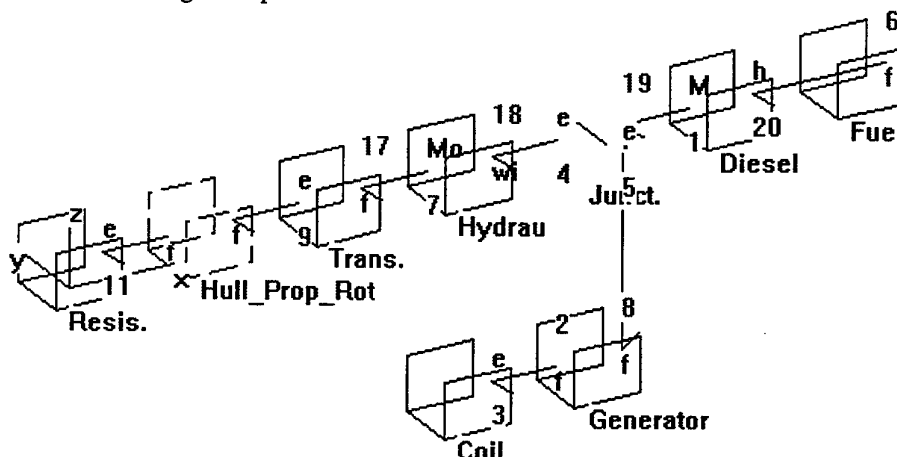
The sort numbers disappear by redrawing the model.

Remark: Sort numbers are internal rank values of the effort and flow functions. These sort numbers are generated by GES if you perform a simulation, else all sort numbers are zero.

2.3.5 Options menu

- **Connect** is a cursor mode to connect apparatuses.
- **Disconnect** is a cursor mode to disconnect apparatuses.
- **Copy** copies a selected apparatus.
- **Mantle** is a cursor mode to mantle apparatuses.
- **Dismantle** is a cursor mode to dismantle apparatuses.
- **Mask** prevents a mantled apparatus for calculation.
- **UnMask** unmasks a mask apparatus.
- **Lock** locks a mantled apparatus.
- **Unlock** unlocks a locked apparatus.
- **Delete** deletes a selected apparatus.
- **Delete All** deletes the model.

2.3.5.1 Connect (Options menu)

This option sets the cursor in the **Connect** mode. In this mode you can connect apparatuses together. A necessary condition for connecting apparatuses is that the gate flows must be different as well as the gate variables (effort and flow).

If you choose an open gate a line is drawn between the gate and the cursor. If you click on the gate of the connecting apparatus GES checks the connection conditions. If the connections are successful a connection is made.

In a special case you can connect an apparatus gate to an already connected apparatus pair. In this situation GES calculates some conditions and shows a message to generate an 1- or 0- junction. The user must estimate whether the new generated junction between the apparatuses is practically useful. See the following example:
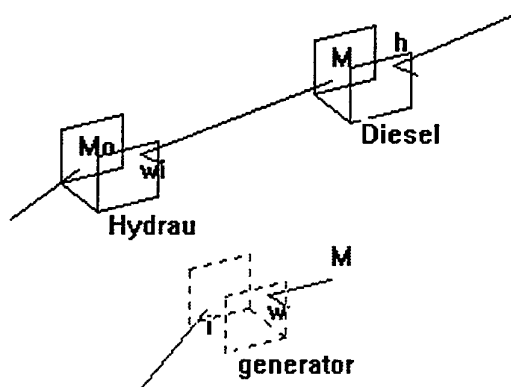
In this example we will connect the generator to the Diesel shaft. The Diesel engine delivers the speed (is a flow) of the system and is connected to a hydraulic system. You can see that the Diesel engine may also be connected to the generator (same energy and variable conditions). If the cursor is

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set into the **Connect** mode and we want to connect the generator to the Diesel shaft, GES gives the message "generate 1-junction" as follows:
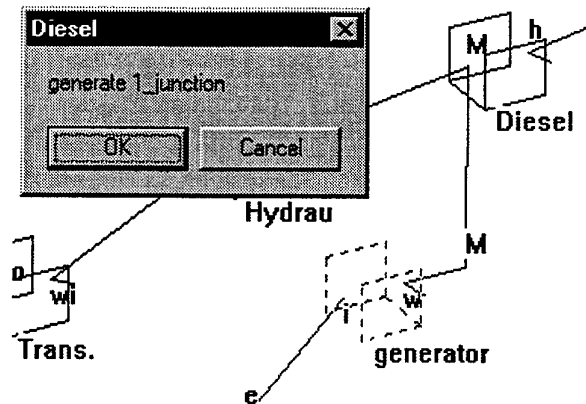
GES has established that a 1-junction generation between the apparatuses is possible. The property of a 1-junction is that for every gate the flow is equal (in this situation this is the shaft speed).

In the following example you can make a connection, but the connection is not practically correct. The model contains two Diesel engines. These engines both deliver a flow variable. We want to connect the shafts. A 0-junction is not correct because for a 0-junction the effort (torque) of all the gates is the same.
To solve the problem one Diesel must calculate a torque variable or you must place a *f_distributor apparatus* between the Diesel engines.
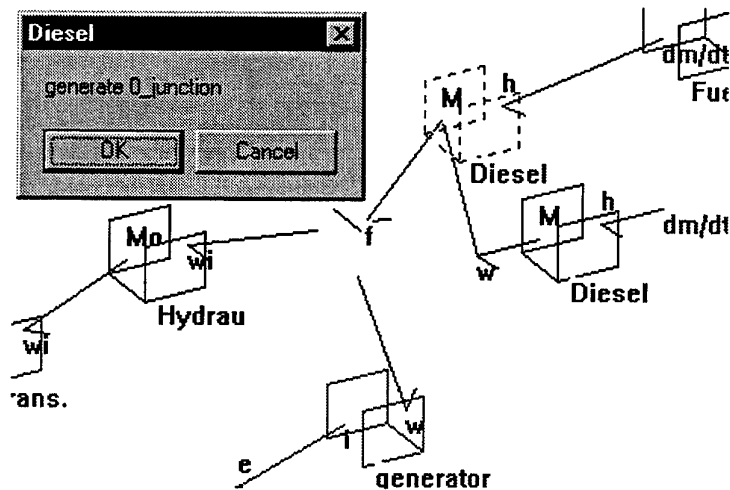
2.3.5.2 Connect gate to mantle apparatus (Connect mode)

If your *mantle apparatus* has free gates you can connect a free apparatus to the mantle by dragging the mouse to the edge of the window. If you click in the edge area a list of free gates of the *mantle apparatus* is displayed. See for instance the following example:
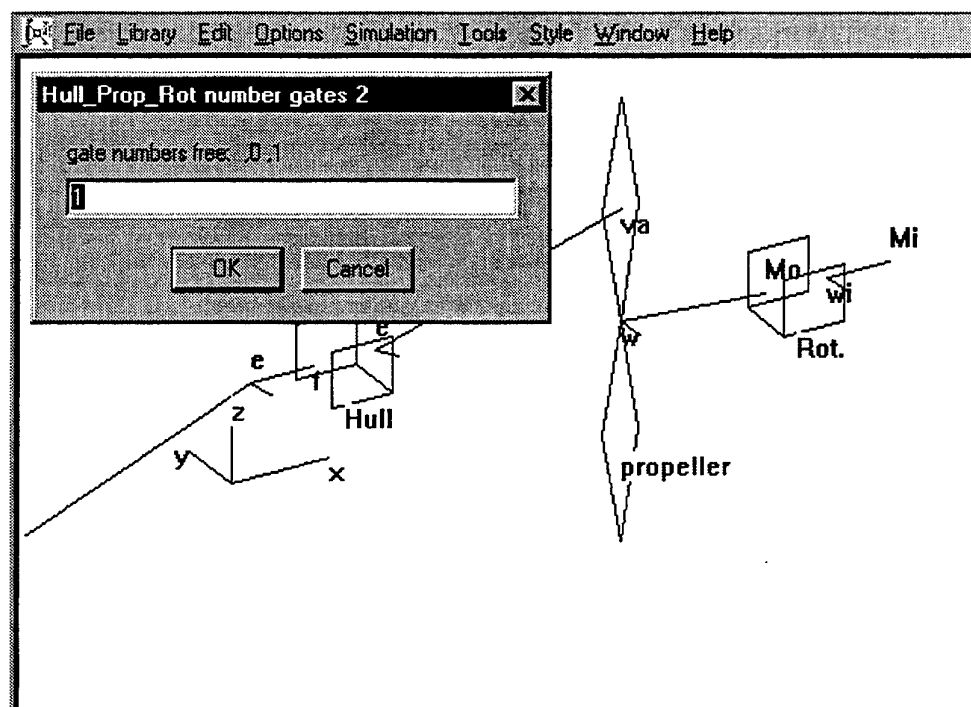
The *mantle apparatus* is the *Hull_Prop_Rot apparatus* from the benchmark. This mantle apparatus has two free gates, numbers 0 and 1. In this example the free gate of the *hull apparatus* is chosen. By default GES takes the last number 1, but you can also choose another by typing 0.

2.3.5.3 Disconnect (Options menu)

This option sets the cursor in the **Disconnect** mode. In this mode you can disconnect apparatuses by clicking on a connected gate. If the apparatuses are disconnected they are drawn with there default gate vector values. It is possible that a default gate vector lies on the old connection line. In that case you cannot always see whether the disconnection is correct. In case of doubt you can drag an apparatus.

2.3.5.4 Copy (Options menu)

If this item is active you can copied the selected apparatus. See also 2.3.4.2 Edit equations (Edit menu), page 32.

2.3.5.5 Mantle (Options menu)

With this option you set the cursor in the mantle mode. In this mode you can put apparatuses in one apparatus (the mantle apparatus). If you set the cursor in this mode and you select an apparatus, than this apparatus is first mantled. This *mantle apparatus* has the same number of gates as the selected apparatus. The selected apparatus is in the *mantle apparatus* and is connected inside. The name of the *mantle apparatus* starts with **m_** and is appended with the name of the first selected apparatus.
If you do not leave the **Mantle** mode all following selected apparatuses are put into the *mantle apparatus*. If the selected apparatus has connections with other apparatuses the number of gates of the mantle apparatus is adjusted. The minimum number of gates is always one because otherwise you could not select the apparatus.
The *mantle apparatus* is drawn with a dotted line.

2.3.5.6 Dismantle (Options menu)

With this option you can set the cursor in the **Dismantle** mode. In this mode you can remove the mantle apparatuses in your model by selecting them. The mantle apparatus is recognized as an apparatus that is drawn with a dash-and-dot line. If a mantle apparatus is dismantled the apparatuses inside are show in the window.

2.3.5.7 Mask (Options menu)

With this option you can mask a selected *mantle apparatus*. You mask an apparatus for preventing it to be calculated. If you want to mask a not-mantled apparatus you must first mantle the apparatus.
A masked apparatus is drawn with a thick blue line. If the selected apparatus is correct the following window is opened.
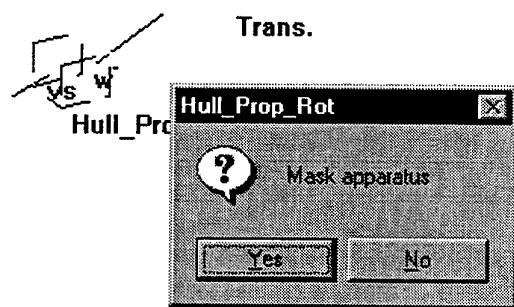
Remark:
With a *run apparatus* you can simulate mask apparatuses individually.

2.3.5.8 UnMask (Options menu)

With this option you can unmask a masked apparatus. A masked apparatus is drawn with a thick blue line. If the selected masked apparatus is correctly chosen the following window is opened.
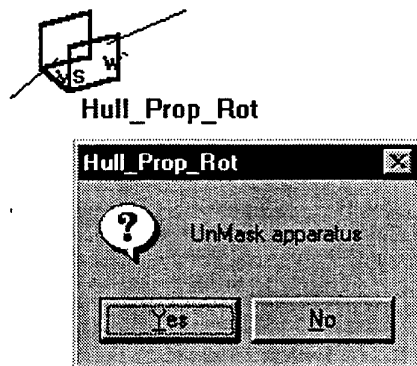
2.3.5.9 Lock (Options menu)

With this option you can prevent to go in a mantled apparatus. A locked apparatus is drawn normally. If you select a locked apparatus in the edit equations mode you can look in this apparatus. In a further version of GES we want to give the locked apparatus its own global workspace.

2.3.5.10 UnLock (Options menu)

Unlocks a locked apparatus.

2.3.5.11 Delete (Options menu)

With this option you can delete a selected apparatus. If the selected apparatus is correct the following window is opened.
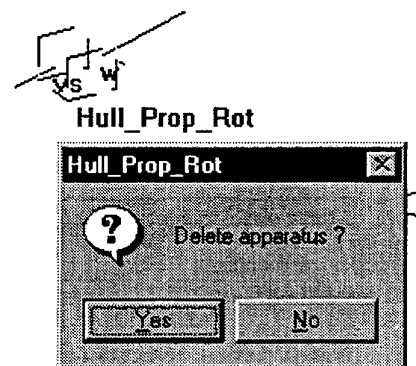
Remark:

You can also delete an apparatus by pressing on the **Del** key after the apparatus is selected.

2.3.5.12 Delete All (Options menu)

With this option you can delete the complete model. This option is only active in the first model window, else the menu bar is grayed. If you delete the model all objects are removed from memory, except the system workspace.

2.3.6   Simulation menu

The **Simulation** menu consist of eight sub-parts:
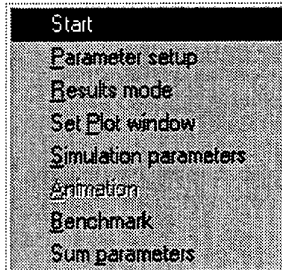
- **Start** starts a simulation dialog box. The name is **Stop** when the program is running.
- **Parameter setup** is used for changing the parameters in steps.
- **Results mode** is a cursor mode to display the results.
- **Set Plot window** sets a screen to plot results data in 2D.
- **Simulation parameters** displays a dialog box with iteration values.
- **Animation** makes an animation of a selected apparatus.
- **Benchmark** inserts a propulsion installation in an empty window.
- **Sum parameters** calculates the sum of parameters with the same name.

2.3.6.1   Start (Simulation menu)
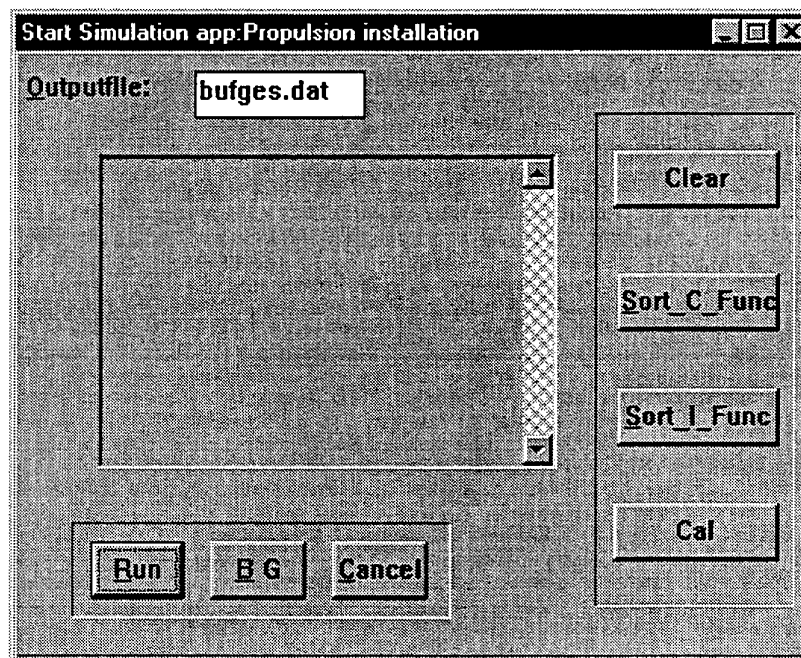
With this menu you can calculate your model at three methods.

- Manually by clicking on **Clear, Sort_C_Func, Sort_I_Func** and then by clicking on **Cal.**
  - **Clear** sets all gates at zero. These are the starting values of the iteration process.
  - **Sort_C_Func** sorts all explicit functions.
  - **Sort_I_Func** sorts all implicit functions and the remaining explicit functions.
  - **Cal** starts the simulation of the sorted functions.
- In the foreground by clicking on the **Run** button. The simulation starts in the foreground with a specified number of steps.

- By clicking on the **BG** button. The simulation starts in the background continuously.

The status of the calculation is displayed in the list box.

2.3.6.2 Parameter setup (Simulation menu)
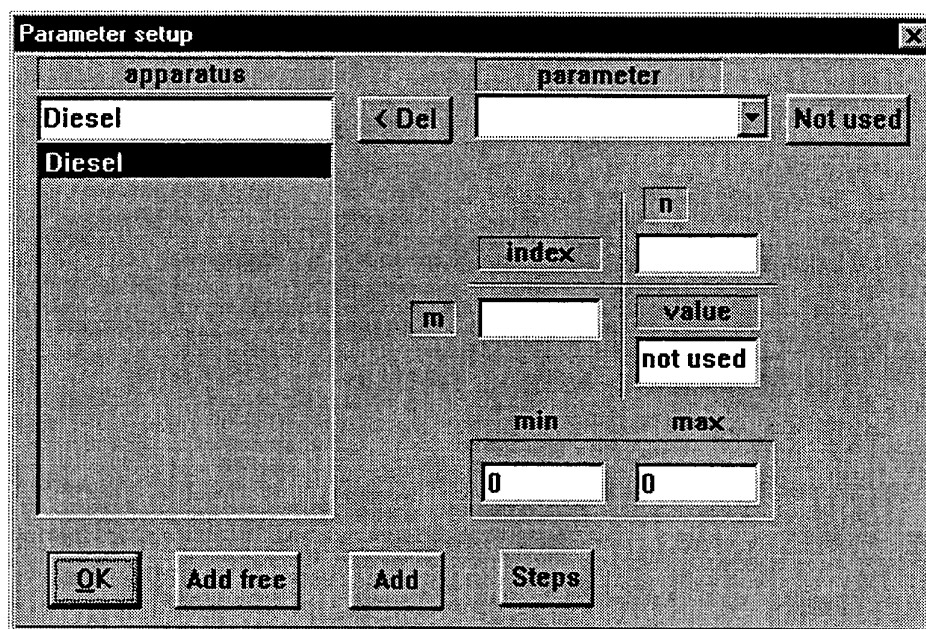
In this menu you can change the parameters of an apparatus in a few steps. In the **apparatus** list box the apparatuses are listed for changing a parameter. You select a parameter of an apparatus in the **parameter** list drop box. If the selected parameter is a matrix you must set the element indexes in the **m** and **n** fields. The actual parameter value is given in the **value** field. In the **min** and **max** fields you must set the minimum and maximum required value of the parameter.

By clicking on the **Del** button you can remove an apparatus from the **apparatus** list and with the **Not used** button you can skip a parameter for changing.

Steps button

You can set the number of steps with the **Steps** button. The following dialog box is displayed.
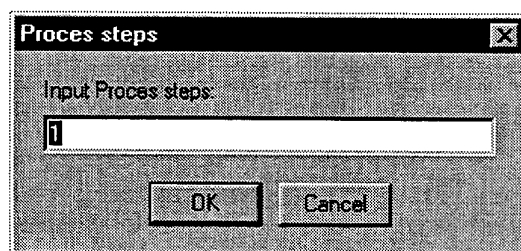
The default number of steps is one. For varying a parameter from the minimum until the maximum value a step size of 100 is recommended.

Add button
You can insert an apparatus in the **apparatus** list by clicking on the **Add** button. The **Parameter setup** dialog box is closed. The cursor is set in the **parameter setup** mode. If you select an apparatus in your model the **Parameter setup** box is displayed with the new added apparatus in the list. You can add more apparatuses and setup the minimum and maximum values.

Add free button
With this option it is possible to change the input variables (effort or flow) of the free gates of an apparatus in steps.
If you click the **Add free** button, all apparatuses with free gates are inserted in the **apparatus** list. For every free gate the apparatus is inserted. If you select an apparatus in the **apparatus** list the free gate number is displayed in the **value** field as gate : * . The user can set the minimum and maximum value to change the gate by steps.

2.3.6.3 Results mode (Simulation menu)

With this option you set the cursor in the **Results** mode. If you click on a gate of an apparatus a dialog box is displayed with all calculation results of the selected apparatus.
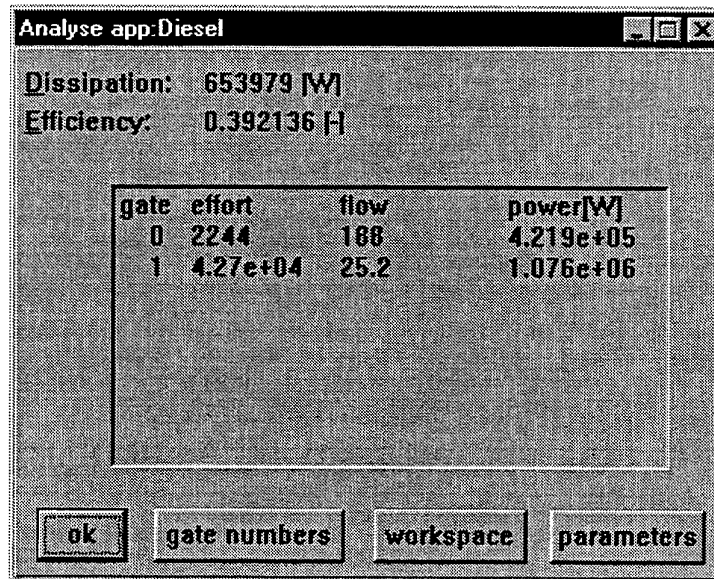
For the complete apparatus the dissipation and efficiency are calculated. The efficiency is zero for an apparatus with one gate. For every gate the effort and flow variable is listed. The power of every gate is calculated.

If you click on the **gate numbers** button the gate numbers are drawn into the model. See also 2.3.4.5 Draw gate numbers (Edit menu), page 35. If you click on the **OK** button the dialog box is closed.

By clicking on **workspace** the local- and global workspace is displayed. If the system variable *view_syswrkspc=1* in the initialization file GES.INI is set to 1 the system workspace is also displayed.

By clicking on **parameters** the parameter list of the apparatus is displayed. See also 2.3.4.1 Edit parameter values (Edit menu), page 28.

If you select another apparatus a new results dialog box is displayed over the old one. You can move the results dialog boxes to compare the results.

2.3.6.4 Set Plot window (Simulation menu)

This menu sets a **plot window** for plotting your results. See 2.4 Plot window, page 54.

2.3.6.5 Simulation parameters (Simulation menu)

The default values for the iteration process are given in the following dialog box.
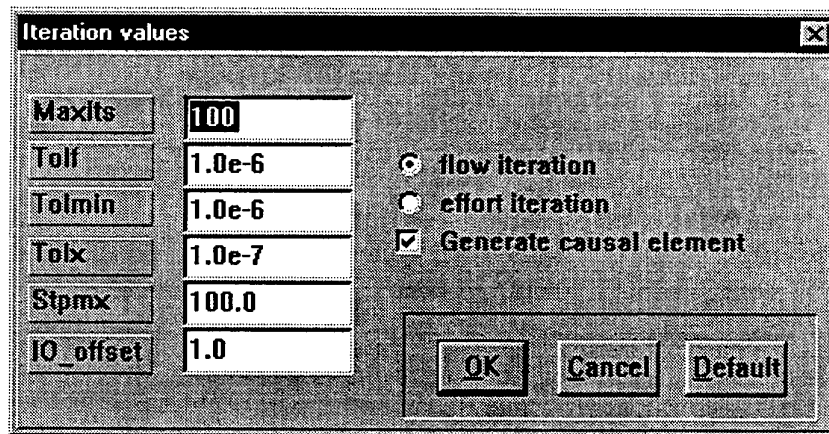
- **Maxits** is the maximum number of iterations.
- **Tolf** sets the convergence criterion of function values.
- **Tolmin** sets the criterion for deciding whether spurious convergence to a minimum of a function has occurred. The function value is checked until **Tolmin** a real minimum has occurred. If the new step is too close to the old step size this check is made if the convergence is spurious.
- **Tolx** is the convergence criterion on the step size.
- **Stpmx** is the scaled maximum step length allowed in line searches.
- **IO_offset** is the offset value of the starting values of the iteration process.

Effort or flow iteration

With the radio buttons you can choose whether GES first searches for a **flow** or an **effort** function at the iteration equations.

For instance if the equations for iteration are $e1=g1(f2)$ and $f2=g2(e1,constant)$. The function in the **flow iteration** mode is: $f2=g2(g1(f2),constant)$. $e1$ in this mode is calculated directly.

In the **effort iteration** mode the iteration function is: $e1=g1(g2(e1,constant))$. In this mode $e1$ is solved by iteration and $f2$ is calculated directly.

Generate causal element

With this option **on**, GES generates automatically a causal element if two apparatuses with the same variable type (effort, effort or flow, flow) are connected.

By clicking on **Default** you can make the chosen iteration values default followed by clicking on **OK** in the following dialog box.
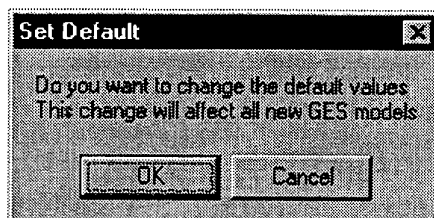
The default values are set in the GES.INI file.

2.3.6.6 Animation (Simulation menu)

With the animation option you can move the selected apparatus. The orientations of the apparatus are read from a binary file. If you choose this menu a dialog box is displayed with the directory name.
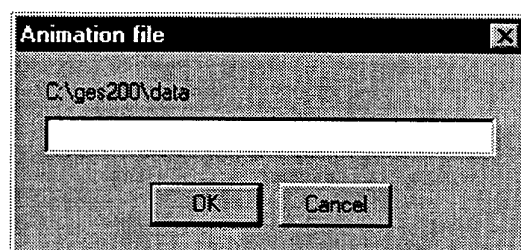
The binary animation file must contain the position and the rotation information. The information is sequentially read. Each time the apparatus drawing is cleared and redrawn with the new orientations until the end of the file is reached.

2.3.6.7 Benchmark (Simulation menu)

If the model is empty this menu gives a benchmark of a propulsion installation of a ship. You can use this model for learning how GES works and for making a start for a new propulsion installation.
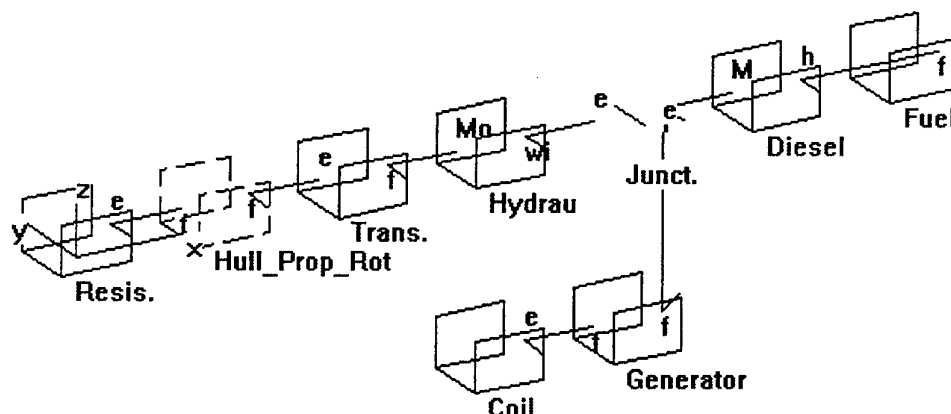
Figure 3   Benchmark of a propulsion installation

Remark:

Not all apparatuses in the benchmark are derived from the import library, because they where constructed in the design phase. It is possible to change an apparatus with the equivalent import library apparatus. The results must be the same. For a GES starter this is a nice lesson.

2.3.6.8 Sum parameters (Simulation menu)

With this option is it possible to calculate the sum of the parameters with the same first name in the model. If you choose this menu the following dialog box is displayed.

In the field **Name** you must set the parameter name. If you click on the **Cal** button, GES adds all parameter values with the 'same first name' together. This is done from the window where the calculation is started. The result is set in the **Value** field.

By comparing the parameters the names are not case sensitive. The first blanks are skipped and all characters after the first word are not taken into account.

For instance if the parameter word is *mass*. GES adds the values of the parameter names: *mass engine*, *mass propeller* and *mass gearbox*, but not *transmission mass*.

2.3.7 Tools menu

The user can run four tool programs with GES. The default programs are Mossel, Quaestor and Notepad. It is possible to run other programs by editing the entry tool(1, 2, 3, 4) in the GES.INI file. The names in the menu are default. The programs or links must placed in the root directory of GES.
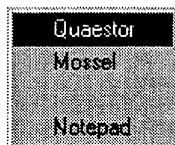
Mossel starts the batch file Mossel.bat for calculation of aspect values.
Quaestor starts the batch file Quaestor.bat.
Empty place.
Notepad starts Notepad.exe

2.3.7.1 Quaestor (Tools menu)

The tool program Quaestor is started by the .bat file *Quaestor.bat*

The file *Quaestor.bat* contains:

```
cd \
cd c:\q\programs
qst.exe
```

qst.exe is the Quaestor program.

2.3.7.2 Mossel (Tools menu)

The tool program Mossel is started by the .bat file *mossel.bat*. The batch file must be in a directory given by the system path name. The program Mossel calculates coefficients to characterize a gas turbine or a diesel engine. The program GES uses these coefficients.

The file *mossel.bat* contains:

```
cd \
cd c:\mossel
mossel.exe
mos_ges.exe gesem.dat c:\ges\data\mossel.par
```

mossel.exe is the Mossel program.

If you stop the program Mossel, Mossel writes its results to the file *c:\mossel\gesem.dat*. This file is not in GES format. The program *mos_ges.exe* translates the file *c:\mossel\gesem.dat* to the file *c:\ges\data\mossel.par*. You can read this file in the parameter fields of the apparatus *diesel_exhaust*. See for the description of this apparatus 3.3.2 Diesel exhaust, page 99.

2.3.8 Style menu

Rotate X axis
Rotate Y axis
Rotate Z axis
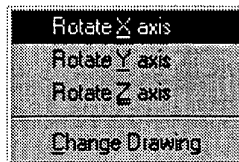
Change Drawing

- **Rotate X axis** Rotates a selected apparatus about the X-as.
- **Rotate Y axis** Rotates a selected apparatus about the Y-as.
- **Rotate Z axis** Rotates a selected apparatus about the Z-as.
- **Change Drawing** changes the drawing of a selected apparatus

2.3.8.1 Rotate X axis (Style menu)

Rotates a selected apparatus about the X-as.

2.3.8.2 Rotate Y axis (Style menu)

Rotates a selected apparatus about the Y-as.

2.3.8.3 Rotate Z axis (Style menu)

Rotates a selected apparatus about the Z-as.
First you must select an apparatus. The selected apparatus is written with a dotted line.
By clicking on this menu the selected apparatus is rotated on the global z-axis. The rotate menu
rotates the selected apparatus by 90 degrees respectively.
Examples of the apparatus orientations:

0 degrees   90 degrees   180 degrees   270 degrees
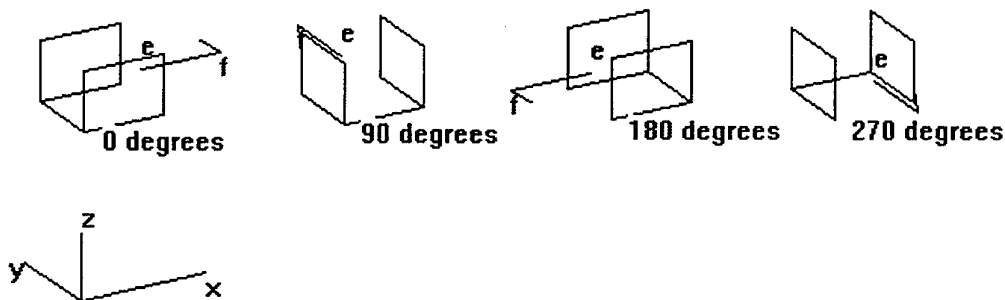
Figure 4   Apparatus rotations in the z-direction

2.3.8.4 Change drawing (Style menu)

You can change a drawing by first selecting an apparatus. The selected apparatus is written with a
dotted line. **Change drawing** in the **Style** menu displays a dialog box with the name of the selected
apparatus.

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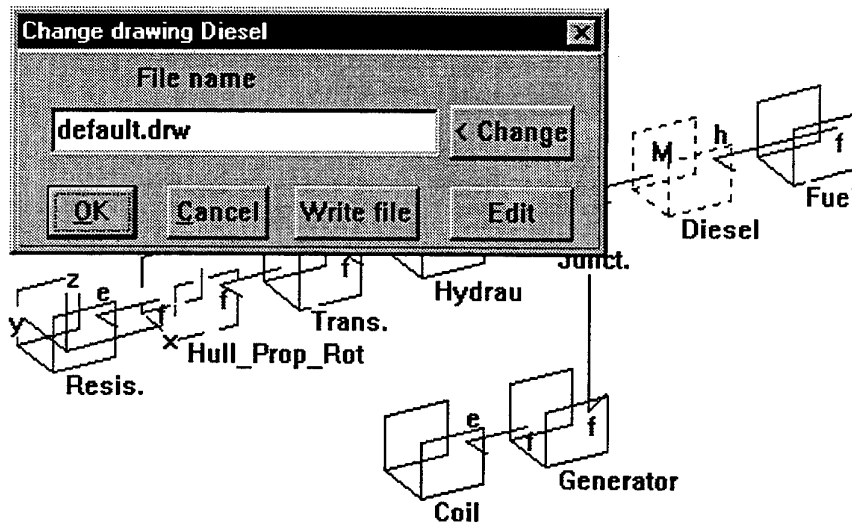
By clicking on the **OK** button the drawing is read from file (default file is *default.drw*) and loaded into the apparatus. You can change the file with the **Change** button. If you click on the button **Write file**, the drawing of the selected apparatus is written to the file given by the **File name** field. If you click on **Edit** the *notepad* editor (for Windows) is started and gives the code of the drawing in text format. The format of the drawing is:

Text format of the drawing. Format code between the brackets [   ] is optional.

(Number of points) (number of columns) [x scale] [y scale] [z scale] [comment]
x-position y-position z-position **line-output #** [line color] [comment]
 	
  .   .   .   .   .
  .   .   .   .   .
 	
[(number of gates)
(gate number)   x-position y-position z-position   //start of energy vector
(gate number)   x-position y-position z-position   //end of energy vector
                                       //empty line
(gate number)   x-position y-position z-position
(gate number)   x-position y-position z-position]

Table 2   Drawing format

The **number of points** is usually the number of x-y-z-values. This number may be less than the real numbers given in the file. The **number of columns** must be 4 for figures without a line color (default color is black). If you want to give the **line-output** functions an individual color, the **number of columns** must be 5.

The x y and z scale factors are optional and are used to size the incoming **line-output** functions. The default value is 1. The comment is optional and can be 64 characters in length.

The x-y-z-positions are floating point values of at least 10 characters in length. The x-y-z-positions must be given in local coordinates.

There are 4 **line-output** functions:

line-output functions	line-output #	number of x-y-z-positions	Description
line	1	2	draws a line
poly line	2 ending with -2	a set	draws a set of line segments
triangle	3	3	draws a triangle
square	4	4	draws a square

Table 3   Line-output functions

You can build your figure by mixing the **line-output** functions.

There are 6 **line colors**:

color	[line color]
black	0
blue	1
green	2
cyan	3
red	4
magenta	5

Table 4   Line colors

Number of gates is the number of gate vectors you want to change. This feature is optional. You can change the position of the gate energy vector, by giving the positions of the start and the end vector. The positions are given by a **gate number** and the **x-y-z-positions**. The **scale-factors [x][y][z]** have no effect on these values. Every position must be written on a new line. Between the gate vectors an empty line (CR) must be inserted.

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Example: Block model of the apparatus diesel (only one poly line)

```
10 4 Diesel
-0.500000  -0.500000   0.000000   2.000000  poly line
 0.500000  -0.500000   0.000000   0.000000
 0.500000  -0.500000   1.000000   0.000000
-0.500000  -0.500000   1.000000   0.000000
-0.500000  -0.500000   0.000000   0.000000
-0.500000   0.500000   0.000000   0.000000
 0.500000   0.500000   0.000000   0.000000
 0.500000   0.500000   1.000000   0.000000
-0.500000   0.500000   1.000000   0.000000
-0.500000   0.500000   0.000000  -2.000000  end poly line
2 nr gates
  0  -0.500000   0.000000   0.500000
  0  -1.500000   0.000000   0.500000

  1   0.500000   0.000000   0.500000
  1   1.500000   0.000000   0.500000
```

2.3.9 Help menu

See 2.2 GES MDI window, page 17.

2.4 Plot window

In a **plot window** you can plot your results as a linear graph of 2D data. You can also make a set of data. If you choose this menu a window for plotting your data is opened. You can open more than one **Plot window**.
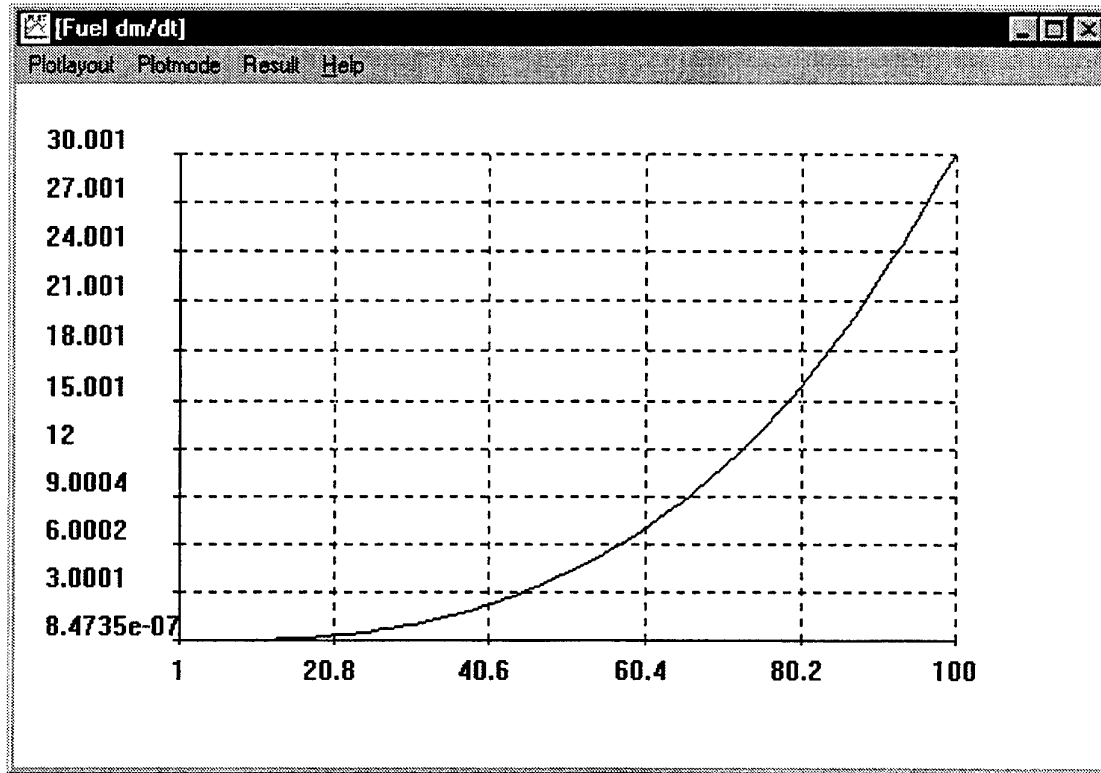
If you click on one of the gates of an apparatus and there is data available this data is plot in the plot screen. The default data variable is the flow of the gate. The default X axis is the number of steps. The Y axis is automatically scaled (XY AUTOPLOT). In the **Result** menu you can change this mode. If there are more **Plot windows** than one, you can select the screen by first clicking in the plot screen area with the mouse cursor.

2.4.1 Plot layout

- **Print** displays a print dialog box to print the plot.
- **Set world** displays a dialog box, with world coordinates.
- **Plot style** displays a dialog box, with plot sizes.
- **Make Y data X axis** changes the X axis with the actual Y axis.
- **Make X axis steps** changes the X axis with step numbers

In the **plot layout** menu, you can print a plot, set the axis world for fixed axes plotting, set the plot style and change the X axis data.

Clicking on **Print** displays a print dialog box to print the plot.

Clicking on **Set world** displays the following dialog box, with default values:

```
┌─────────────────────────────────────────────┐
│ plot world                              [X]  │
│                                              │
│           min            max                 │
│                                              │
│   X axis  [0        ]    [1        ]         │
│                                              │
│   Y axis  [0        ]    [1        ]         │
│                                              │
│                                              │
│        [  OK  ]   [ Cancel ]   [ Default ]   │
│                                              │
└─────────────────────────────────────────────┘
```

You can set in the **min** and **max** axis fields the minimum and maximum value of the X axis and the Y axis. These values are used if you plot data with fixed axes (XY DATAPLOT). If you click on the **OK** button the values are accepted. If you click on the **Default** button the default values are set. Clicking the **Plot style** menu displays the following dialog box to change axis' size and positions.

```
┌─────────────────────────────────────────────┐
│ plot style                              [X]  │
│                                              │
│              X axis        Y axis            │
│                                              │
│  axis orig. [0.15    ]    [0.2     ]         │
│                                              │
│  axis size  [0.7     ]    [0.7     ]         │
│                                              │
│  axis point [0.15    ]    [0.2     ]         │
│                                              │
│  divisions  [5       ]    [10      ]         │
│                                              │
│  axis on    [✓] on/off    [✓] on/off         │
│                                              │
│  color      [1       ]    [4096    ]  print size │
│                                              │
│  grid on    [✓] on/off    [✓] on/off         │
│                                              │
│  label on   [✓] on/off    [✓] on/off         │
│                                              │
│  header     [0.5     ]    [0.5     ]         │
│                                              │
│        [  OK  ]   [ Cancel ]   [ Default ]   │
│                                              │
└─────────────────────────────────────────────┘
```

The values in the dialog box are the default values.

The axes' origins are expressed in the following figure:

1,1

Axis point and data origin

Axis origin

0,0
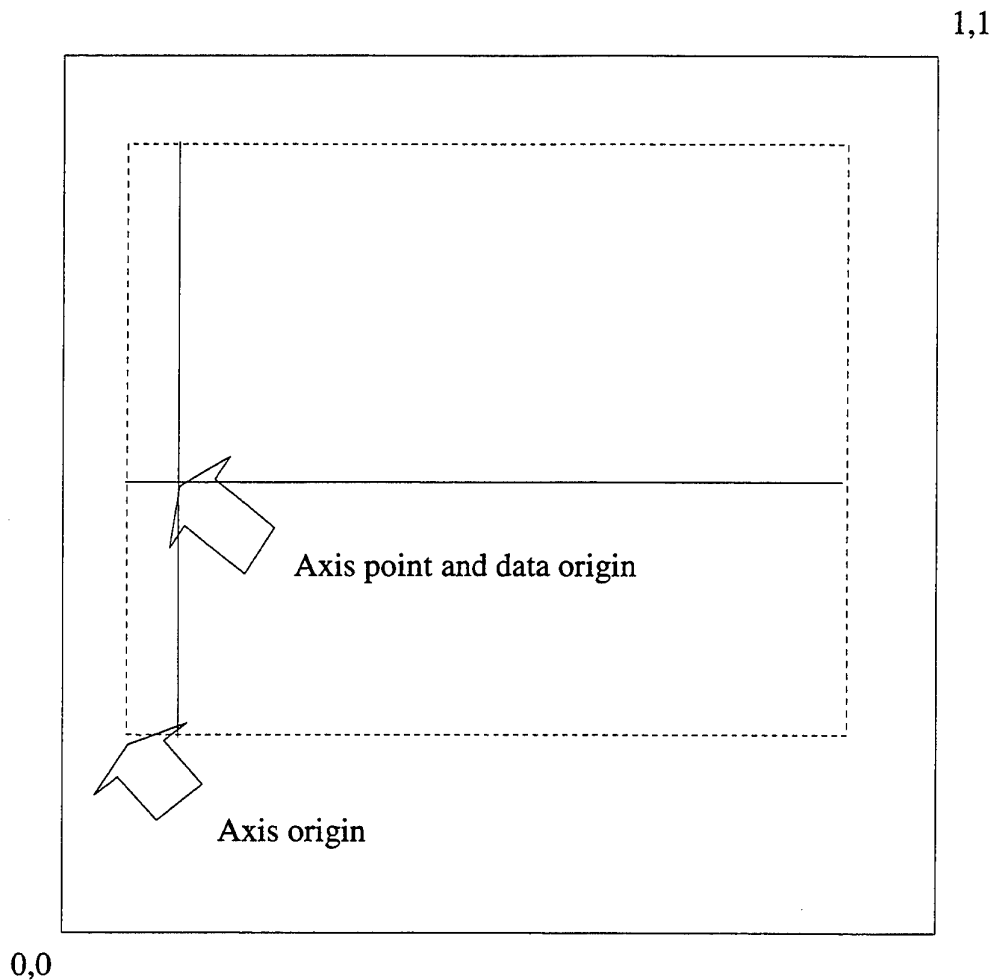
Figure 5   Diagram plot axes

The axes are described in logical values.

axis orig. specifies the origin of the axis area as a fraction of the overall area. Values can range from 0 to 1.

axis size specifies the size of the axis area as a fraction of the overall window area. The values can range from 0 to 1.

axis point is a position within the window where the X and Y axes intersect.

divisions specifies the number of thick marks for the axes.

In the **print size** field you can resize your print. This value is also used for printing the model. See also 2.3.1.7 Print (File menu), page 25.

3 Import library

The GES library consists of eight sub-libraries:

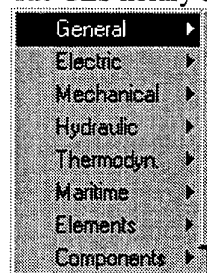| General ► |
| Electric ► |
| Mechanical ► |
| Hydraulic ► |
| Thermodyn. ► |
| Maritime ► |
| Elements ► |
| Components ► |

- **General** is a sub-library for general apparatuses.
- **Electric** is a sub-library for electric apparatuses.
- **Mechanical** is a sub-library for mechanical apparatuses.
- **Hydraulic** is a sub-library for hydraulic apparatuses.
- **Thermodyn.** is a sub-library for thermodynamic apparatuses.
- **Maritime** is a sub-library for maritime apparatuses.
- **Elements** is a sub-library for element apparatuses.
- **Components** is a sub-library for ideal apparatuses.

3.1 General library

The general library consist of seven apparatuses and or groups:

- **User defined** displays a dialog box to set up a *user defined apparatus*.
- **Quaestor interface** is an entry to select interface apparatuses.
- **Parameter change** is an entry to select apparatuses to change parameters.
- **Workspace** is an entry to select apparatuses with the global workspace.
- **Init gate** sets a gate variable in the model. Used for iteration processes.
- **Failure module** displays a dialog box to create a *switch apparatus*.
- **Run apparatus** starts a simulation of an *apparatus*.

3.1.1 User defined

See 5.6 Program, page 178.

3.1.2 Quaestor interface (signal type)

With this menu two types of apparatuses can be created: the *epi apparatus* and the *epo apparatus*. The *epi apparatus* reads data from file and the *epo apparatus* writes data to file. The input and output file must have the same structure (the "Telitab" format). The structure is:

"number"		total number of values between semicolons. Fe. "3". there are following now 3 groups
"1"	value	first number between semicolons (field 10 characters) and a floating point value
"2"	value	second number between semicolons (field 10 characters) and a floating point value
.	.	et cetera
"number"	value	last number between semicolons (field 10 characters) and a floating point value.

Table 5   "Telitab" format

It is possible to use both apparatuses for an interface with other programs.

The program Quaestor uses batch programs with this file structure for communication with the outside world. To synchronize the communication between the batch program and the GES program a flag file is used as a semaphore. The communication is as follows. The batch program must make the flag file and the *epi apparatus* must wait for the flag file. Then the batch program must wait until the flag file is removed. If GES is ready witch the calculations GES must create an epo file and remove the flag file. This happens only if there is an *epo apparatus* in the system. The *epo apparatus* writes only one value to the epo file. For every written value to the epo file an *epo apparatus* must be used.

With the **Quaestor interface** dialog box you can choose an *epi apparatus* or an *epo apparatus*.
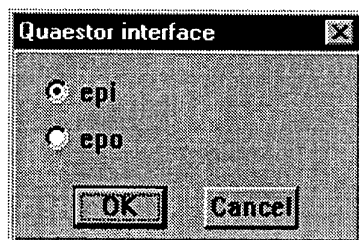
You resume by clicking on the **OK** button.
The name of the chosen apparatus is given in the capture of the following dialog box. The name is the default name of the apparatus type. You can change the name of the apparatus in the text box **name**.
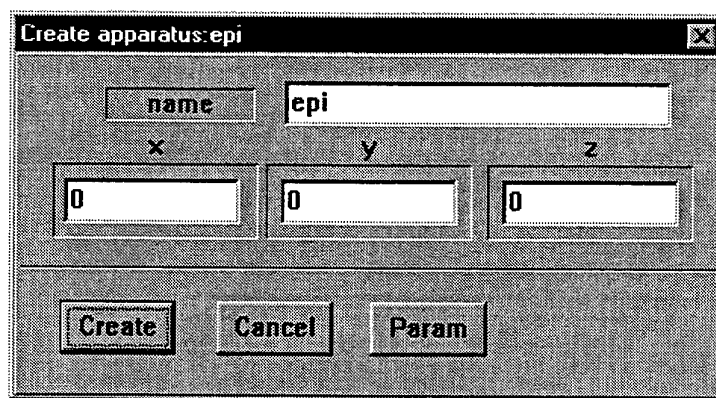
If you click on **Create** the apparatus is set in memory. If in memory you can edit the parameter list of the apparatus by clicking the **Param** button.

3.1.2.1 epi apparatus (signal type)

epi
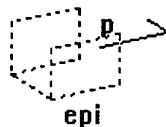
		input			output		
gate	energy	variable	symbol	unit	variable	symbol	unit
0	no	no	p	[-]	flow		[-]

Table 6   Gate variables *epi apparatus*

The *epi apparatus* reads just one value from a text file in epi format from one particular place. This value is set in the parameter list of the connected apparatus. The position in the epi file and the position of the parameter in the connected apparatus must be specified in the parameter list of the *epi apparatus*.

Parameter(0):

    Contains the position in the epi file for reading the value. If the value is 0, then no value is read.

Parameter(1):

    The path and name of the epi file must be placed in the field **Name**. Path and filename maximum 30 characters.

Parameter(2):

    Is the index number of the parameter of the connected apparatus. If the parameter of the connected apparatus is a matrix the position in this matrix must be given by parameter(3) and parameter(4).

Parameter(3):

    This value is the row number of the matrix of the parameter of the connected apparatus. The value is only used if the parameter is a matrix.

Parameter(4):

    This value is the column number of the matrix of the parameter of the connected apparatus.

Parameter(5):

    If **wait for flag** is 0 the *epi apparatus* reads the value from the epi file.

    If **wait for flag** is 1 the epi apparatus reads only the value from the epi file if there is a special file, called the flag file. The name of the flag file is derived from the epi file name. See for the file name parameter(1). The extension of the flag file is *.flg*.

Example: In this example an *epi apparatus* is connected to a *diesel apparatus*. GES executes first the *epi apparatus*. The *epi apparatus* reads one value from an epi file and places this value in the parameter list of the *diesel apparatus*. This could for instance be the speed of the diesel engine.
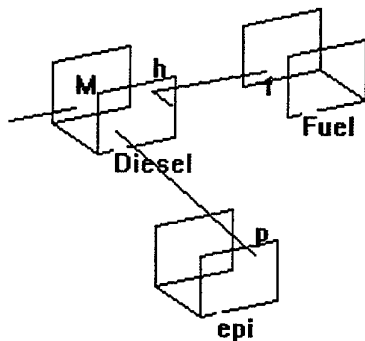
3.1.2.2 epo apparatus (signal type)

epo
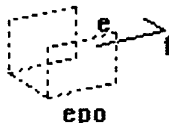
		input			output		
gate	energy	variable	symbol	unit	variable	symbol	unit
0	no	no	e	[-]	flow	f	[-]

Table 7   Gate variables *epo apparatus*

The *epo apparatus* writes result values of one gate to an epo file in a particular place. The values are of the connected apparatus. These values can be the effort, flow and power of one gate of the connected apparatus and the dissipation and the efficiency of the apparatus as a whole. The *epo apparatus* first writes the chosen values in an internal buffer (not visible for the user). After calculation GES writes the values from the buffer to the epo file. You can use more than one *epo apparatus*. All these *epo apparatuses* write in the same buffer, but only one epo file is created. If a position in the epo file is not mentioned in the parameter list of one of the *epo apparatuses* a value of -999999 is placed at that position. The name of the epo file is obtained from the last running *epo apparatus*. It is recommended to use the same epo file name in all *epo apparatuses*. The maximum position number in the parameter list of one of the *epo apparatuses* is its total number of values in the epo file.

Example: an epo file if only one flow value of 1.880000e+02 is written in position 3.

```
3
"1"        -9.999990e+05
"2"        -9.999990e+05
"3"         1.880000e+02
```

If there is a flag file created by another program the flag file is removed.

Parameter(0):

> The effort value of the gate of the connected apparatus. **Value** is the place in the epo file. If
> this value is 0 no effort value is placed in the epo file.

Parameter(1):

> The flow value of the gate of the connected apparatus. **Value** is the place in the epo file. If
> this value is 0 no flow value is placed in the epo file.

Parameter(2):

> The power value of the gate of the connected apparatus. **Value** is the place in the epo file. If
> this value is 0 no power value is placed in the epo file.

Parameter(3):

> The dissipation value of the connected apparatus. **Value** is the place in the epo file. If this
> value is 0 no dissipation value is placed in the epo file.

Parameter(4):

> The efficiency value of the connected apparatus. **Value** is the place in the epo file. If this
> value is 0 no efficiency value is placed in the epo file.

Parameter(5):

> The name of the epo file must be placed in the text box **Name**. Path and filename maximum
> 30 characters.

Parameter(6):

> In **Value** the appropriate gate number of the connected apparatus must be inserted. This
> number is the gate number of the connected apparatus.

Example: In this example an *epo apparatus* is connected to a *diesel apparatus*. GES executes first all the normal apparatuses. After calculation the *epo apparatus* writes a few selected values (selection: effort, flow, power, dissipation, efficiency) of one of the diesel engine gates (0 or 1) to an internal buffer. This is first done for all *epo apparatuses*. Then GES creates one epo file with all these results. A possible flag file is removed.
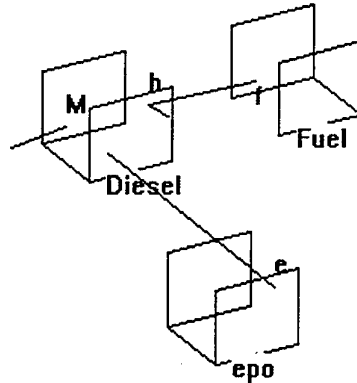
3.1.2.3 Quaestor interface example

Quaestor is a DOS program which calls the batch program interface. The batch program is a stand-alone program that communicates with the outside world through a set of files. The communication files between the interface and Quaestor have the extension .epi for standard input files and .epo for standard output files. They both have the TELITAB format. The interface program can read the epi file and must create the epo file. For communication with GES the interface program must create another epi file, for example we choose the extension .gin. After that a flag file for synchronization needs to be created by the interface program. The interface program shall wait until the flag file is removed. If GES is ready with the calculation it creates an epo file with extension .gou and it removes the flag file. Next the interface program reads the .gou file and creates an epo file. If the interface program is ready, Quaestor can read the epo file.
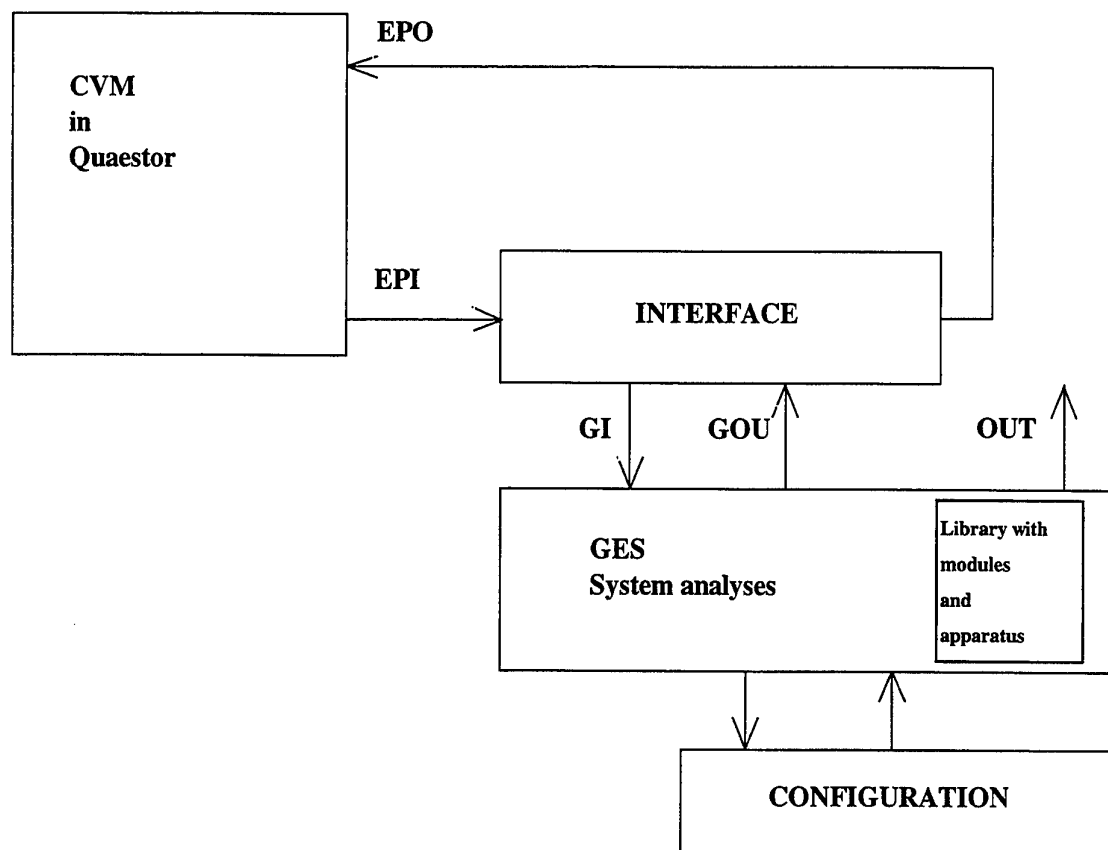
Figure 6   Interface configuration

Import library, General library

Example:
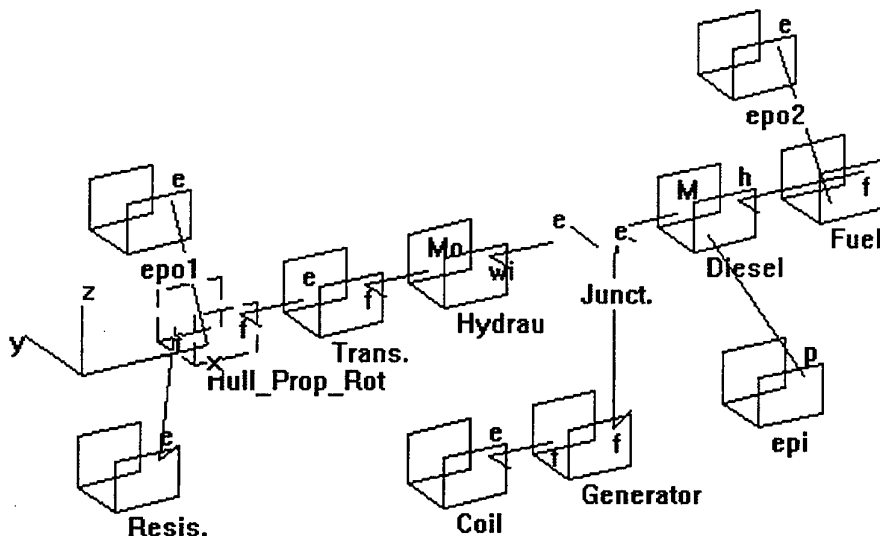An example of a GES model with one *epi* and two *epo apparatuses* is given in Figure 7.

Figure 7   Interface model with *epi* and *epo apparatus*

For continues communication with other programs GES must calculate in the background mode for a few steps the user can use the foreground mode.

The *epi apparatus* reads the speed of the diesel engine from an epi file *intface.gin*. For synchronization the parameter(5) *wait for flag* must be 1. The speed value is placed in parameter(0) of the diesel engine. If the flag file \q\interface.flg exists GES resumes the calculation. The last apparatuses in the calculation list are the two *epo apparatuses*. For instance the *epo1 apparatus* writes the velocity of the ship to the epo file \q\interface.gou and the *epo2 apparatus* writes the fuel mass flow to the epo file. Than GES removes the flag file and the interface program can read the epo file.

This example model can run without the Quaestor interface program, if the *wait for flag* option in the *epi apparatus* is set to zero.

See for this model *ges\examples\epi_epo.mod*.

The example epi file *example.gin* is also in *ges\examples*. Position two in the epi file gives the speed of the diesel engine.

The *epo1 apparatus* sets the speed of the ship at position two in the *ges\examples\gesintf.epo* file.

The *epo2 apparatus* sets the fuel consumption on position three in *gesintf.epo*.

3.1.3 Parameter change

If a total energy system model is built it is possible to set some particularly gate values in the system by changing a few parameter values of the apparatuses automatically.

To change parameters in the system we need at least two types of apparatuses: the *set apparatus* and the *par apparatus*. The *set apparatus* is used as set point in the system and the *par apparatus* is used as apparatus for the parameter changes. There must always be a pair. GES gives a warning if there is not a pair. You can find this warning for background calculation in the log file.

GES solves the system of more than one pair of *set-par apparatuses* with a Newton-Rapson method for non-linear systems. This is the same method for solving the energy system equations of GES. The iteration limits can be changed in 2.3.6.5 Simulation parameters (Simulation menu), page 46.

With the **Parameter change** dialog box you can choose a *set apparatus* or *par apparatus*.
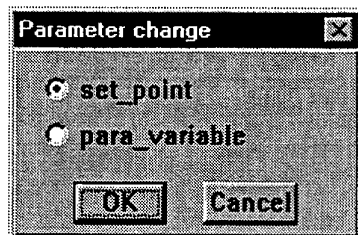
You resume by click on the **OK** button.

The name of the chosen apparatus is given in the capture of the following dialog box. The default name is **set** for a *set apparatus* and **par** for a *par apparatus*. You can change the name of the apparatus in the text box **name** before the apparatus is created.
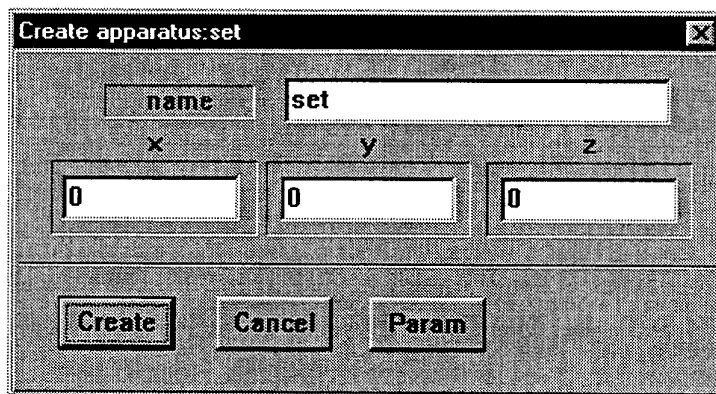
3.1.3.1 set apparatus (signal type)

set
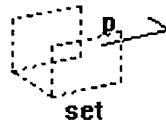
		input			output		
gate	energy	variable	symbol	unit	variable	symbol	unit
0	no	no	p	[-]	flow		[-]

Table 8   Gate variable *set apparatus*

The *set apparatus* is used as a set-point in the system. The *par apparatus* changes a parameter in the system until the set-point value is reached. You must always use a *set apparatus* with a *par apparatus* as a pair. GES solves the system for more than one pair of *set-par apparatuses*. The set-point value can be the flow, effort or power of a gate. In the parameter list of the *set apparatus* you choose the set-point variable and the gate number of the connected apparatus that you will use as a set-point.

Parameter values: set

Index	Name	Value	Unit
0	set point	0	[-]
1	effort[0],flow[1],power[2]	0	[-]
2	connected gate nr	0	[-]

Up   Down   Add Par   Read file   Write file   Plot mat   OK   Cancel

Parameter(0):

This parameter is the set-point value. The energy type is defined with parameter(1).

Parameter(1):

is the number of the set-point type. There are three types: 0, 1, 2.

set-point type 0 is the effort of the gate.

set-point type 1 is the flow of the gate.

set-point type 2 is the power of the gate.

Parameter(2):

This parameter is the gate number of the controlled gate of the connected apparatus. Running GES changes the *par apparatuses* until the set-point values of the controlled gates are reached.

Import library, General library

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3.1.3.2 par apparatus (signal type)

par
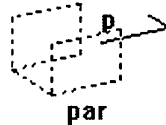
		input			output		
gate	energy	variable	symbol	unit	variable	symbol	unit
0	no	no	p	[-]	flow		[-]

Table 9 Gate variables *par apparatus*

The *par apparatus* changes a parameter of the connected apparatus until the set-point value of the *set apparatus* is reached. You must always use a *par apparatus* and a *set apparatus* together.

Parameter(0):

  Is the iteration start value of the parameter change routine in GES. It is recommended to use an expected value in the neighborhood of the solution. If there are more solutions you must choose this value properly.

Import library, General library

Parameter(1):

> Is the index number of the parameter of the connected apparatus. If the parameter of the connected apparatus is a matrix the position in this matrix must be given by parameter(3) and parameter(4).

Parameter(2):

> This value is the row number of the matrix of the parameter of the connected apparatus. This value is only used if the controlled parameter is an element of a matrix.

Parameter(3):

> This value is the column number of the matrix of the parameter of the connected apparatus. This value is only used if the controlled parameter is an element of a matrix.

Parameter(4):

> You can use this parameter to change other parameters of some apparatuses at the same time. The output value (changing parameter value) of this apparatus could be set in an internal global buffer of GES (indicated by a number between 0-99) or set in the global workspace (recommended).

Example:

In Figure 8 a GES example is given for changing a parameter (by the *par apparatus*) of the diesel engine until the set-point value of the *set apparatus* is reached. The set-point value could be the flow (the speed of the ship) of the gate between the *Hull_Prop_Rot apparatus* and the *Resis. apparatus*.
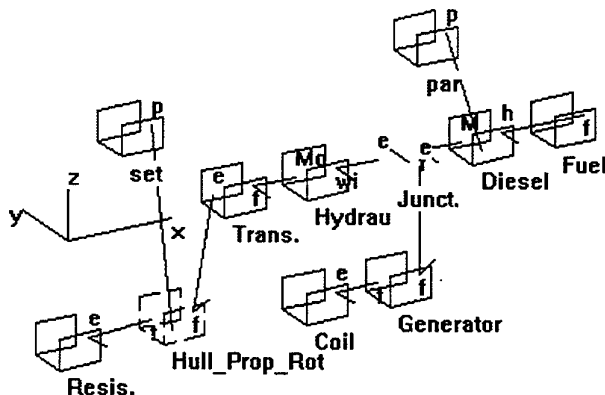
Figure 8   Parameter changing with *set-* and *par apparatus*

See *set par example* in model *ges\examples\set_par.mod*.

3.1.4 Workspace

In this menu you can select two *workspace apparatuses*. These apparatuses are used to read and write values to and from the global workspace. Mostly these apparatuses are used to read and change energy- and parameter values of import library apparatuses.

Remark: With the *user defined apparatus* you can easily write and read to and from the global workspace. In that case these apparatuses are not necessary.

3.1.4.1 to_workspace (signal type)
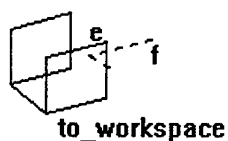
to_workspace

		input			output		
gate	energy	variable	symbol	unit	variable	symbol	unit
0	no	no	e	[-]	flow	f	[-]

Table 10   Gate variables *to_workspace apparatus*

The *to_workspace apparatus* is used to place energy values of a particular gate of an apparatus in the global workspace variables.

Remark: A global workspace variable is a name with at least 30 characters and marked with an exclamation mark (!).

Parameter values: to_workspace	⊠	
Index Name	**Value**	**Unit**
0 effort >	0	[-]
1 flow >	0	[-]
2 power >	0	[-]
3 dissipation>	0	[-]
4 efficiency >	0	[-]
5 parameter >	0	[-]
6 parameter index	0	[-]
7 dim parameter m:	0	[-]
8 dim parameter n:	0	[-]

Up   Add Par Read file Plot mat OK Cancel

Down   Write file

Parameter(0):

> Gives the global variable where the effort of the inspected gate of the connected apparatus is set. If this value is 0 no setting is done.

Parameter(1):

> Gives the global variable where the flow of the inspected gate of the connected apparatus is set. If this value is 0 no setting is done.

Parameter(2):

> Gives the global variable where the power of the inspected gate of the connected apparatus is set. If this value is 0 no setting is done.

Parameter(3):

> Gives the global variable where the dissipation of the connected apparatus is set. If this value is 0 no setting is done. The inspected gate value (parameter(5)) must be one of the gates.

Parameter(4):

> Contains the global variable where the efficiency of the connected apparatus is set. If this value is 0 no setting is done. The inspected gate value (parameter(5)) must be one of the gates.

Parameter(5):

> The inspected gate number of the connected apparatus.

Parameter(6):

> The inspected parameter number (index) of the connected apparatus.

Parameter(7):

> The inspected parameter element row number if the inspected parameter of the connected apparatus is a matrix.

Parameter(8):

> The inspected parameter element column number if the inspected parameter of the connected apparatus is a matrix.

3.1.4.2 **from_workspace** (signal type)

from_workspace

		input			output		
gate	energy	variable	symbol	unit	variable	symbol	unit
0	no	no	p	[-]	flow		[-]

Table 11   Gate variables *from_workspace apparatus*

The *from_workspace apparatus* is used to place the value of a global workspace variable in a parameter of an apparatus.

Parameter(0):

     For a number this is the index of the internal global buffer of GES (indicated by a number between 0-99). For a global workspace variable (recommended) this must be a name followed by an exclamation mark. For a system workspace variable this must be a name followed by two exclamation marks.

Parameter(1):

     The index of the parameter of the connected apparatus. If this parameter is a matrix element, the indices must be given by parameter(2) (row) and parameter(3) (column).
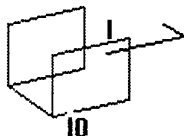
Parameter(2):

     The row number in the matrix. This value is used if the parameter of the connected apparatus is a matrix.

Parameter(3):

     The column number in the matrix. This value is used if the parameter of the connected apparatus is a matrix.

3.1.5 Init gate (signal type)

		input			output		
gate	energy	variable	symbol	unit	variable	symbol	unit
0	no	no	I	[-]	flow		[-]

Table 12   Gate variables *init gate apparatus*

The *init gate apparatus* can be used to set a gate value of an apparatus. This can be the effort or flow value of a gate. Because GES uses the actual gate values as the starting points for the iteration process this apparatus can be used as initialization for the iteration process.

Before you use this apparatus, you must first find out which variables in the model are solved by iteration. You can do that by typing manually the sort numbers in the **Edit** menu. An automatic iteration list for setting this values is not worked out in GES. Therefore, you must use this apparatus for difficult iteration processes.

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Index	Name	Value	Unit
0	init value	0	[-]
1	effort[0],flow[1]	0	[-]
2	init gate number	0	[-]

Up   Down   Add Par   Read file   Write file   Plot mat   OK   Cancel

Parameter(0):

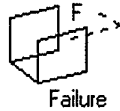The *start point value* for energy solution at a particular gate.

Parameter(1):

The gate variable type effort or flow that is set. 0 is effort. 1 is flow.

Parameter(2):

The gate number of the connected apparatus where the *start point value* is set.

See 3.5.3 Example; Thermodynamic cycle, page 122.

3.1.6 Failure module (signal type)

Failure

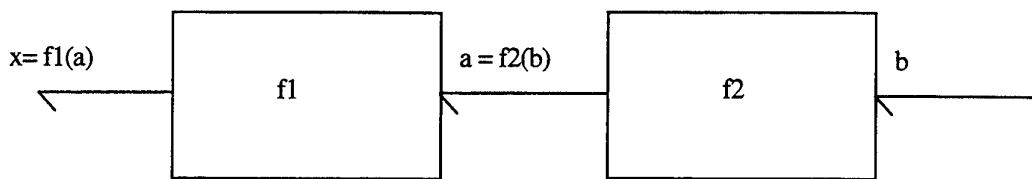|		input			output		
gate	energy	variable	symbol	unit	variable	symbol	unit
0	no	no	F	[-]	signal	-	[-]

Table 13   Gate variables *failure module*

The creation dialog box for this apparatus is:

The failure module is a signal type apparatus and is executed after the calculation of the energy apparatuses. This makes it possible to change the probability failure values during the energy calculation. So a probability variable can be a function of an effort and or a flow variable.

The failure module calculates the fail probability of the connected apparatus. This is the *top apparatus*. The method that is used is the "Fault Tree Analysis". The failure tree is started from the top apparatus and is branched by its input energy gate. There are a few rules to build a fault tree.

- A positive gate is defined as an input. In a graphical representation this is a half arrow to the apparatus. When building the fault tree the outputs of an apparatus are not considered. The tree is started from the inputs of an apparatus to the connected apparatuses. If the input is not connected a structure error in the parameter list of the failure module is generated.

- The fault of an apparatus is assumed to be disjunctive with its inputs and the fault must be less then 0.1 so the following calculation rules can be used.
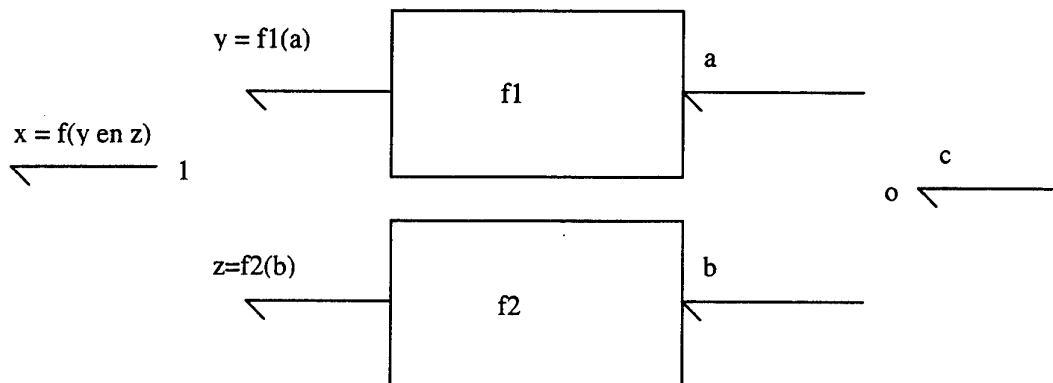
  For apparatuses in *series* the following configuration is given:

Import library, General library

```
x= f1(a)      ┌──────────┐   a = f2(b)    ┌──────────┐   b
              │          │                │          │
  ───────────│    f1     │───────────────│    f2     │─────────────
              │          │                │          │
              └──────────┘                └──────────┘
```

For these apparatuses the following calculation is done:

P(x) = P(f1 or a) = P(f1 or P(f2 or b)) = P(f1 or f2 or b) = P(f1) + P(f2) + P(b)

For apparatuses connected *parallel* the following configuration is given:

```
        y = f1(a)      ┌──────────┐   a
                       │          │
            ──────────│    f1     │─────────────
                       │          │
  x = f(y en z)        └──────────┘
                                                        c
  ────────── 1                                       o
        z=f2(b)        ┌──────────┐   b
                       │          │
            ──────────│    f2     │─────────────
                       │          │
                       └──────────┘
```

The calculated probability of P(x) is:

P(x) = P(f) + P(y) * P(z)   ;P(f)=0 (connection)

    P(y) = P(f1 or a) = P(f1) + P(a)

    P(z) = P(f2 or b) = P(f2) + P(b)

    P(a) = P(c)

    P(b) = P(c)

P(x) = (P(f1) + P(c)) * (P(f2) + P(c))

Worked out:

P(x) = P(f1) * P(f2) + P(f1) * P(c) + P(f2) * P(c) + P(c) * P(c)
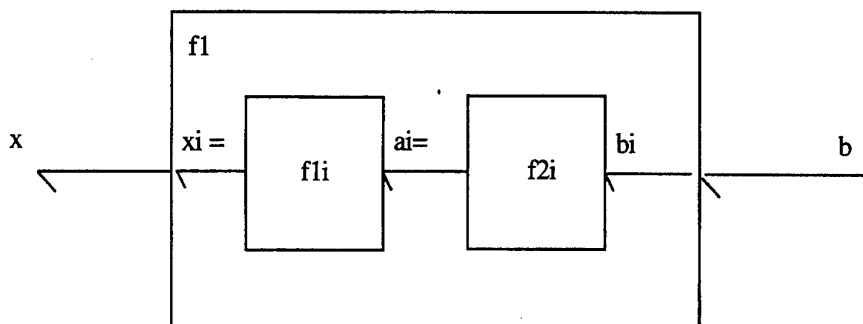
Import library, General library

With the reduction rules:

P(c) * P(c) = P(c)

P(f2) * P(c) + P(c) = P(c)

P(x) = P(f1) * P(f2) + P(c)

- Apparatuses inside an apparatus are taken up in the fault tree if they have effect in the energy calculation of the apparatuses in the fault tree. Of course, these apparatuses can be a complete new tree.

For instance:

P(x) = P(f1) and P(f1i) and P(f2i) and P(b)

or

P(x) = P(f1) + P(f1i) + P(f2i) + P(b)

The parameter list of the failure module is:

Index	Name	Value	Unit
0	probability result	0.5722	[-]
1	fail variable	P0_1	[-]
2	structure error	0	
3	calculation error	0	

Parameter values: Fail

Buttons: Up, Down, Add Par, Read file, Write file, Plot mat, OK, Cancel

Parameter(0): (output value)
> Result of the calculation is placed in the value field.

Parameter(1): (input string)
> The failure module calculates with the probability variable string given in the value field. The variable name is the expected local workspace variable that is used as the probability variable in the apparatuses.

Parameter(2): (output value)
> Structure error: If the connections of the apparatuses are not correct to calculate the probability an 1 is set into the value field and name of the wrong connected apparatus is set in the unit field.

Parameter(3): (output value)
> Calculation error: If by calculation the probability result is greater than 1 the calculation is stopped and an 1 is set into the value field. The name of the last calculated apparatus is set in the unit field.
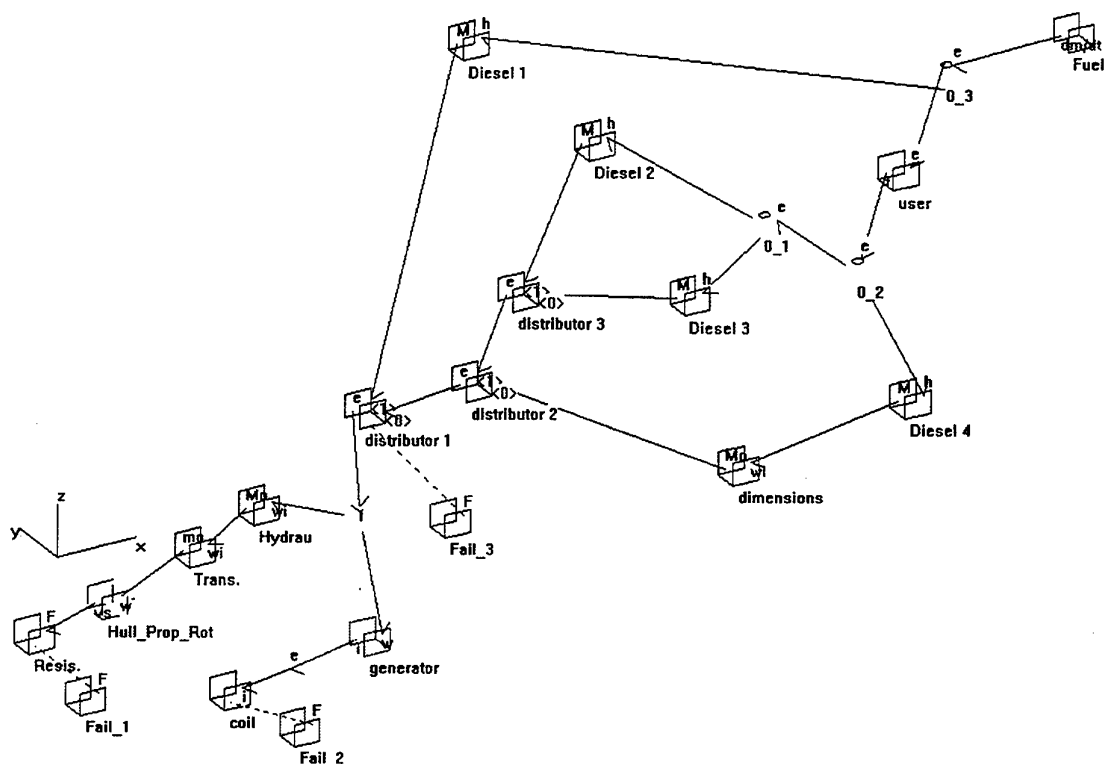
Example:

Figure 9 Example of a propulsion installation with three failure modules

In this example a propulsion installation is given with three diesel engines and three independent failure modules. Failure module **Fail_1** calculates the probability when the propulsion installation fails. Failure module **Fail_2** calculates the probability of coil failure and the failure module **Fail_3** calculates the failure probability of the diesel engine group.
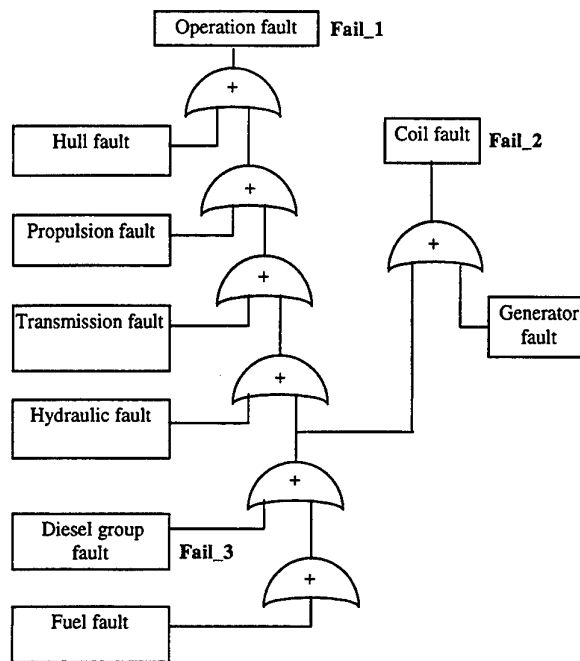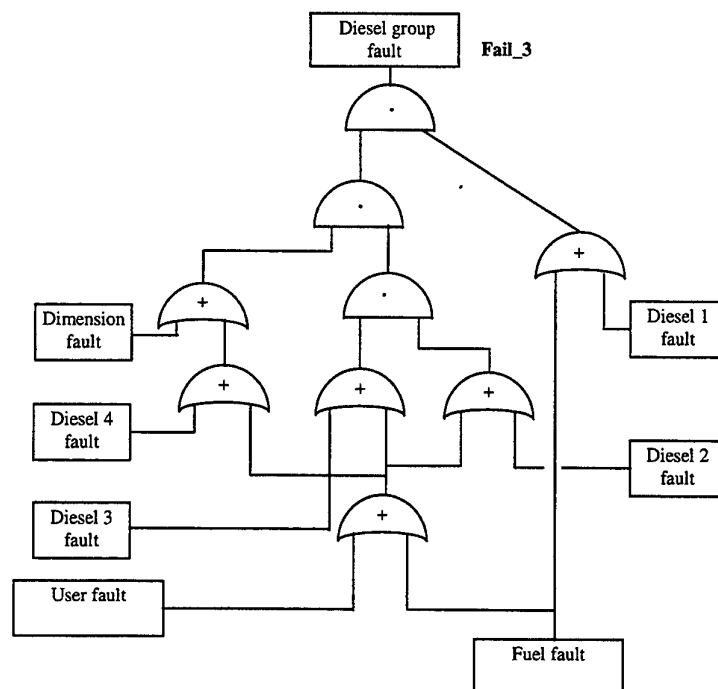

Figure 10 And/or fault tree for example

Figure 11 And/or fault tree for diesel group

3.1.7 **Run apparatus** (signal type)

Run

		input			output		
gate	energy	variable	symbol	unit	variable	symbol	unit
0	no	no	r	[-]	flow		[-]

Table 14 Gate variables *run apparatus*

The *run apparatus* is used to run an apparatus individually. The *run apparatus* runs its connected apparatus if its parameter control flag is set to 1. To run the connected apparatus properly it is recommended to run only mask apparatuses, because the mask apparatuses are not placed in the calculation list.

Remark: If the connected apparatus is not a mask apparatus then this connected apparatus is running twice, once by the global running process and once by the *run apparatus*. This may give illegal results.

Parameter(0):

     The control flag for running the connected apparatus of the *run apparatus*. If this value is 0
no connected apparatus is running. If this value is 1 the connected apparatus is running
individually. You can control your application by using a global variable for the flag variable.
Other apparatus models can change the flag variable to start and stop the connected
apparatus.

Import library, General library

Example:

In the next figure a configuration of a *run apparatus* in a model is given. The flag variable in the *run apparatus* is set by an *epi apparatus* with name gin1.
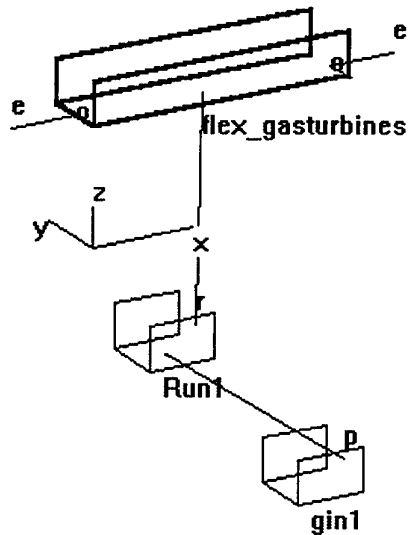

Figure 12   Example *run apparatus* configuration

The *Run1 apparatus* and *gin1 apparatus* are signal apparatus types. The mask apparatus *flex_gasturbines* is running if parameter(0) of the *Run1 apparatus* is 1. In this example this is indirectly set by the *gin1 apparatus*. The *gin1 apparatus* reads the parameter value from file and sets this value in parameter(0) of the *Run1 apparatus*.

3.2 Electric library

| Generator |
| Generator standard |

- **Generator** is a commutator machine
- **Generator standard** is a standard 3 phase electrical alternator

3.2.1 Generator
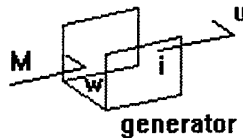
generator

gate	energy	input			output		
		variable	symbol	unit	variable	symbol	unit
0	pos	flow	w	[rad/s]	effort	M	[Nm]
1	neg	flow	i	[A]	effort	u	[V]

Table 15   Gate variables *commutator*

This apparatus describes a simple commutator machine which is operated as a generator. Its speed is determined by the characteristics of its prime mover. It is convenient to classify commutator machines as generators or motors, depending on the dominant direction of the power flow in the application. Commutator machines normally operate with direct voltage supplies and are usually referred to as direct-current machines. They are widely used in vehicles that have electric storage batteries, as motors for auxiliary equipment, and as starters. A major area of use for the motors is in the variable-speed drives where the ability to control speed and position is important.
The relations of the ideal generator are:

$T = K\ I$ //torque (T) is linear with the current (I)

$U = K\ \omega$ //voltage (U) is linear with the speed (ω)
      K = electric magnetic field constant (EMF constant)

If we assume that for the generator U is constant and we know the efficiency η of the generator, then the torque is written as:

$T = K\ I\ /\ \eta$

The parameter list of the commutator generator is:

Parameter values: generator

Index	Name	Value	Unit
0	voltage eff.	440	[V]
1	EMF constant	2.3	[Vs/rad]
2	rendement	0.9	[-]

[Up] [Down]   [Add Par]   [Read file] [Write file]   [Plot mat]   [OK] [Cancel]

Parameter(0):

      The output voltage of the generator.

Parameter(1):

      The electric magnetic field constant of the generator.

Parameter(2):

      The efficiency of the generator.

Example: In this example the equations are given if the generator is created with the *user defined* apparatus. First you must create a *user defined* apparatus with 2 gates and 3 parameters.

The parser string may look as follows:

```
//gate(0)is mechanical side   e_gate(0)=torque
//                            f_gate(0)=speed
//gate(1)is the electric side e_gate(1)=voltage
//                            f_gate(1)=current
//parameter(0)=output voltage [V]
//parameter(1)= EMF
//parameter(2)=efficiency


e_gate(0) = f_gate(1)*parameter(1)/parameter(2); //torque T

neg_gate(1);
e_gate(1) = parameter(0);   //output voltage U
```
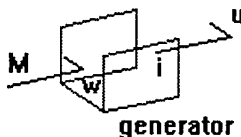
See apparatus *commutator* in model *ges/examples/comu_tor.mod*.

In Appendix B Parser equations of an asynchronous machine, page 214 an example is given of an asynchronous machine. See apparatus asynchrone in model ges/examples/asynaand.mod.

3.2.2 Generator standard

generator

		input			output		
gate	energy	variable	symbol	unit	variable	symbol	unit
0	pos	flow	w	[rad/s]	effort	M	[Nm]
1	neg	flow	i	[A]	effort	u	[V]

Table 16   Gate variables *standard generator*

This apparatus describes a standard three-phase industrial electrical alternator.

Efficiency of the standard alternator
For this apparatus the load dependent efficiency curves for standard alternators are given as polynomial formulas. For each speed an efficiency curve for a larger powered alternator (upper curve) and a lower powered alternator (lower curve) is given. For calculation of the efficiency of alternators with a power size between the upper and lower curve an interpolation according to the cube root will be executed. Also extrapolation of power sizes until 10 % above the upper curve and 10 % below the lower curve can be executed according to the cube root.
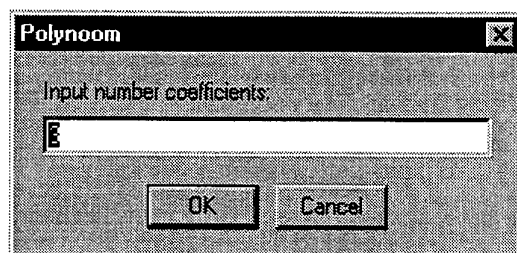
Example of interpolation calculation:

Asked: efficiency at 50 % load of a 1200 rpm alternator of 4000 kW

Calculation: efficiency of a 1200 rpm, 6150 kW alternator at 50 % load is
according to the formula 95.5 %.
efficiency of a 1200 rpm, 350 kW alternator at 50 % load is
according to the formula 91.5 %.
efficiency of a 1200 rpm, 4000 kW alternator at 50 % load can be calculated
with:

$$91.5 + \sqrt[3]{\frac{4000 - 350}{6150 - 350}} \, (95.5 - 91.5) = 94.9 \,\%$$
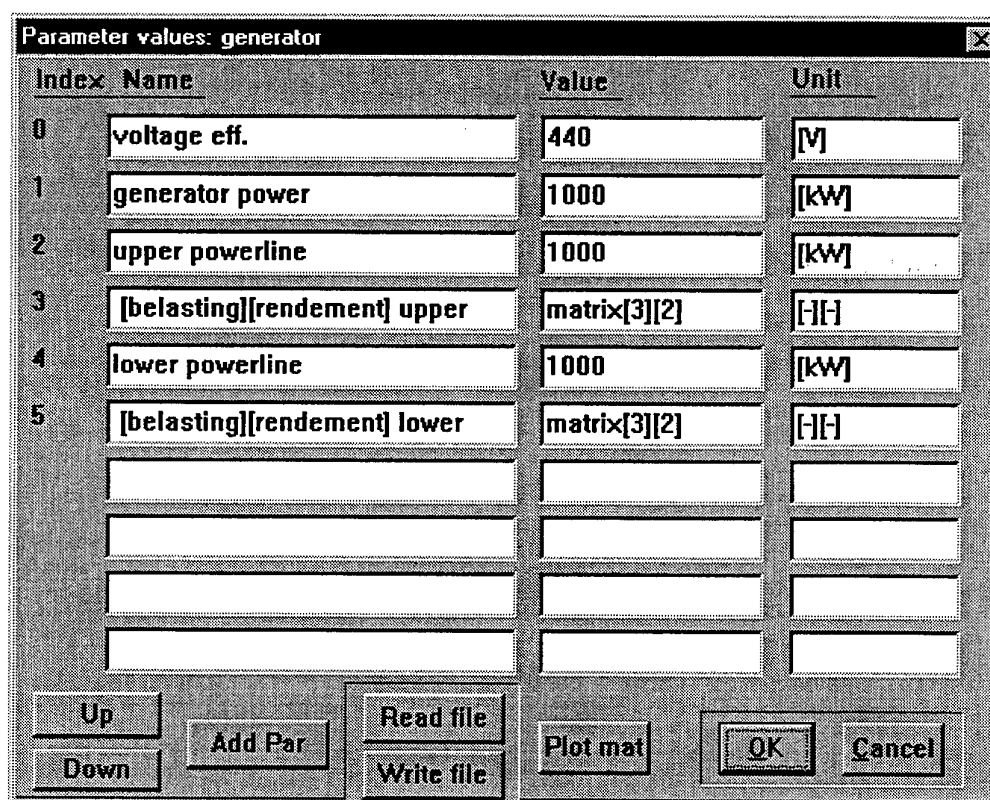
Creating the generator
If you click on **Create** in the create dialog box you must first define the total number of coefficients of your alternator efficiency-load curves. The dialog box is:

Polynoom

Input number coefficients:

[ ]

[OK] [Cancel]

This number is the number of rows of parameter(3) and parameter(5) in the parameter list of the standard generator.

Parameter values: generator

Index	Name	Value	Unit
0	voltage eff.	440	[V]
1	generator power	1000	[kW]
2	upper powerline	1000	[kW]
3	[belasting][rendement] upper	matrix[3][2]	[-]
4	lower powerline	1000	[kW]
5	[belasting][rendement] lower	matrix[3][2]	[-]

[Up] [Add Par] [Read file] [Plot mat] [OK] [Cancel]
[Down] [Write file]

Parameter(0):

The effective output voltage of the standard generator.

Parameter(1):

The nominal power of the generator.

Parameter(2):

The nominal power of the maximum (upper) given generator.

Parameter(3):

Contains the coefficients of the load and efficiency in fractions of the upper power line.

The load fraction is the actual power divided by the nominal power and is placed in column 1. The efficiency (fraction) is placed in column 2.

Parameter(4):

The nominal power of the minimum (lower) given generator.

Parameter(5):

Contains the coefficients of the load and efficiency in fractions of the lower power line.

The load fraction is the actual power divided by nominal power and is placed in column 1.

The   efficiency (fraction) is placed in column 2.

An example of the lower and upper curves are given in the next figure.

The efficiency is given in per cent. In parameter(3) and parameter(4) you must insert the fraction!
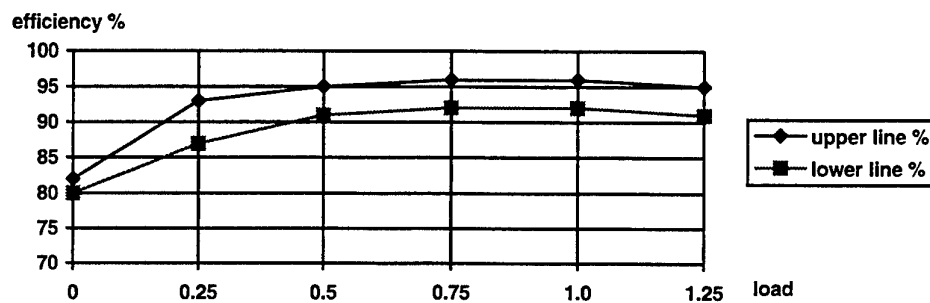

Figure 13   Example lower and upper curves alternator

Example: The efficiency curves of the standard alternator are given as polynomial formulas.

First you must create a *user defined* apparatus with two gates and five parameters.

The parser string may look as follows:

```
// Shaft generator 900 rpm  = 94.2477 rad/s for all voltage
// gate(0) input mechanical energy e = torque[Nm]
//                                  f = speed[rad/s]
// gate(1) output electric energy  e = voltage[V]
//                                  f = current[A]
// parameter(0) = output voltage alternator [V]
// parameter(1) = not used
// parameter(2) = normal load of the alternator in kW
// parameter(3) = normal load of the upper alternator in kW
// parameter(4) = normal load of the lower alternator in kW

name_parameter(0)'voltage';
unit_parameter(0)'[V]';

name_parameter(2)'normal load alternator';
unit_parameter(2)'[kW]';

name_parameter(3)'normal load upper curve';
unit_parameter(3)'[kW]';

name_parameter(4)'normal load lower curve';
unit_parameter(4)'[kW]';

power = e_gate(1)*f_gate(1)/1000; //actual electric power kW
win   = f_gate(0);                    //actual speed in rad/s

pu    = power*94.2477/(parameter(2)*win);    //load fraction

//polynomial curves of the upper and lower lines
//efficiency % of the upper alternator example
eff_max = -6.97*pu^2 + 13.5*pu + 90.4;

//efficiency % of the lower alternator example
eff_min =  8.53*pu^3 - 27.8*pu^2 + 28.5*pu + 83.1;

eff = eff_min + ((parameter(2)-parameter(4)) /
                (parameter(3)-parameter(4)))^(1/3) *
                (eff_max-eff_min);

eff = eff / 100;  //efficiency fraction of the actual alternator

e_gate(0)    = power * 1000 / (win*eff);  //torque shaft

neg_gate(1);
e_gate(1)    = parameter(0);  //output voltage alternator
```
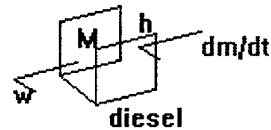
See *alternator* in model *ges\examples\altenatr.mod.*

3.3 Mechanical library

3.3.1 Diesel simple

gate	energy	input			output		
		variable	symbol	unit	variable	symbol	unit
0	neg	effort	M	[Nm]	flow	w	[rad/s]
1	pos	effort	h	[Kj/kg]	flow	dm/dt	[g/s]

Table 17   Gate variables *Diesel simple*

This apparatus describes a simple diesel engine with constant torque over a wide speed range. The power equation of this engine is:

$$T \omega = \eta \, h \, \dot{m}$$

$$\frac{\dot{m}}{T \omega} = fuel\ consumption$$

T is the engine torque [Nm]
ω is the actual speed [rad/s]
h is the enthalpy of the fuel [J/kg]
$\dot{m}$ is the mass flow of the fuel [g/s]
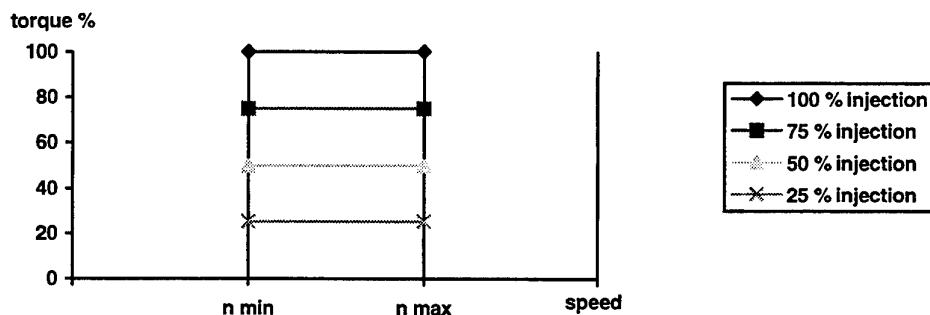η is the efficiency [-]

Figure 14   Torque speed characteristics of the diesel engine

For this model we assume that the efficiency η over the speed range is constant. The minimum and maximum speed of the diesel engine is not taken into account.

Index	Name	Value	Unit
0	velocity	100	[rad/s]
1	specific	215	[g/kWh]

Parameter values: diesel

Buttons: Up, Down, Add Par, Read file, Write file, Plot mat, OK, Cancel

Parameter(0):
        The actual speed of the diesel engine in rad/s.
Parameter(1):
        The fuel consumption of the diesel engine in g/kWh.

Import library, Mechanical library

Example:
You could also create this apparatus with the *user defined* apparatus. The parser equations for this simple model are:

```
//gate(0)is fuel input power, e_gate(0)=h, f_gate(0)= mass //flow
//gate(1)is mechanical output power ; e_gate(1)=T,f_gate(1)=w
//parameter(0) is actual speed in rad/s
//parameter(1) is fuel consumption in g/kWh

neg_gate(1);
f_gate(1) = parameter(0);
//actual speed [rad/s]

f_gate(0) = e_gate(1) * parameter(0) * parameter(1) / 36e5;   //fuel
mass flow [g/s]
```

See *u-diesel apparatus* in model *ges\examples\u_diesel.mod.*

3.3.2 Diesel exhaust
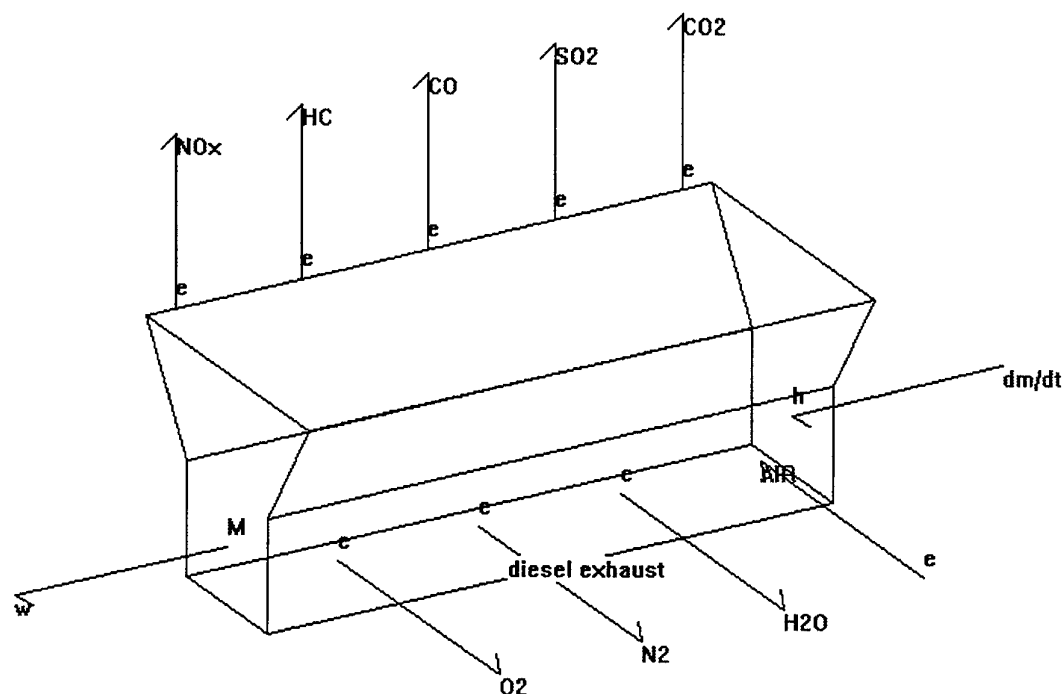
gate	energy	input			output		
		variable	symbol	unit	variable	symbol	unit
0	neg	effort	M	[Nm]	flow	w	[rad/s]
1	pos	effort	e	[kJ/kg]	flow	NOx	[g/s]
2	pos	effort	e	[kJ/kg]	flow	HC	[g/s]
3	pos	effort	e	[kJ/kg]	flow	CO	[g/s]
4	pos	effort	e	[kJ/kg]	flow	SO2	[g/s]
5	pos	effort	e	[kJ/kg]	flow	CO2	[g/s]
6	neg	effort	h	[kJ/kg]	flow	dm/dt	[g/s]
7	neg				flow	O2	[g/s]
8	neg				flow	N2	[g/s]
9	neg				flow	H2O	[g/s]
10	pos	flow	AIR	[g/s]	effort	e	[kJ/kg]

Table 18   Gate variables *diesel exhaust*

For the description of this apparatus see User's Guide version 1.05 reference [2].

The *diesel_exhaust apparatus* replaced the *diesel_emissie apparatus* of GES version 1.00.

Import library, Mechanical library

TNO-report

96-CMC-R0274

GES User's Guide version 1.05

Date

December 15, 1997

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By creation of this apparatus the default values are read from the file GESEM.PAR that must be in the directory C:\GES\DATA. This file contains the default values of the SW280pr diesel engine.

The parameter list of the *diesel_exhaust* apparatus is:

Parameter(0):

Actual speed of the diesel engine.

Parameter(1):

Nominal speed of the diesel engine.

Parameter(2):

 Minimum speed limit.

Parameter(3):

 Nominal power.

Parameter(4):

 Percentage carbon in fuel.

Parameter(5):

 Percentage hydrogen in fuel.

Parameter(6);

 Percentage sulfur in fuel.

Parameter(7):

 A matrix that contains the aspect values of the diesel engine.

matrix[0][0]: nominal fuel consumption	[kg/h]
matrix[1][0]: nominal emission ratio NOx	[g/kg fuel]
matrix[2][0]: nominal emission ratio HC	[g/kg fuel]
matrix[3][0]: nominal emission ratio CO	[g/kg fuel]

Parameter(8):

 Is a matrix that contains calculation values.

matrix[0][0]: equivalence ratio [-].	If gate 10 is not connected this value is an input parameter. The air flow is automatically calculated. Default value is 2.
matrix[1][0]: HC-ratio	[-]	Default value is 2.
matrix[2][0]: fuel consumption	[kg/h]
matrix[3][0]: emission ratio NOx	[g/kg fuel]
matrix[4][0]: emission ratio HC	[g/kg fuel]
matrix[5][0]: emission ratio CO	[g/kg fuel]
matrix[6][0]: emission ratio SO_2	[g/kg fuel]
matrix[7][0]: emission ratio CO_2	[g/kg fuel]
matrix[8][0]: emission ratio O_2	[g/kg fuel]
matrix[9][0]: emission ratio N_2	[g/kg fuel]
matrix[10][0]: emission ratio H_2O	[g/kg fuel]

Remark:

The results of the program Mossel are set in the file GESEM.DAT in the startup directory of Mossel. With the program Mos_ges.exe the results from the file GESEM.DAT are translated to a GES parameter format. The results are set in the file MOSSEL.PAR you can read this file, by pressing on <Read file> button in the parameter list.

It is recommended to start the program Mossel from GES tools, because the program is started by a batch file Mossel.bat. See 2.3.7.2 Mossel (Tools menu), page 49.

3.3.3 Transmission

This apparatus describes a simple general transmission. The speed transmission is assumed to be constant and the torque loss is only dependent of the efficiency factor. The power equations of this model are:

$$T_{out}\,\omega_{out} = \eta\,T_{in}\,\omega_{in}$$

if

$$\omega_{out} = n\,\omega_{in}$$

then

$$T_{in} = T_{out}\,n/\eta$$

T_{out} = output torque [Nm]
T_{in} = input torque [Nm]
n = ratio [-]
η = efficiency [-]

Parameter(0):

The transmission ratio n.

Parameter(1):

The efficiency η.

Import library, Mechanical library

3.3.3.1 Gearbox

This apparatus is not implemented in the import library.

In practice the efficiency of a gearbox is dependent of the part-load. A more detailed model of a gearbox is described here. The following example provides a design for a gearbox with the *user defined apparatus*.

For the off-design of gearbox losses it is assumed that part of the loss is proportional to the transmitted power, that another part is proportional to the transmitted torque and that the balance is proportional to shaft speed.

The equation of the loss of power by part-load is described with the following equation:

$$\frac{P_{loss}}{P_{loss,norm}} = a \frac{P_{in}}{P_{in,norm}} + b \frac{M_{in}}{M_{in,norm}} + c \frac{N_{in}}{N_{in,norm}}$$

P_{loss} is also:

$$P_{loss} = P_{in} - P_{out}$$

If the ratio n of the gearbox is known, the output speed of the gearbox is:

$$N_{out} = n \, N_{in}$$

Practical values for the fractions a, b and c are: 0.4, 0.4, 0.2. See reference [5].

If the input speed and the output torque are known, the output speed and input torque can be calculated with the equations given in the following parser string:

```
//gate(0) input  e_gate(0) = M_in  f_gate(0) = N_in
//gate(1) output e_gate(1) = M_out f_gate(1) = N_out
//parameter(0) = ratio of the gearbox (N_out/N_in)
//parameter(1) = Ploss_norm
//parameter(2) = Nin_norm
//parameter(3) = Min_norm
//parameter(4) = a
//parameter(5) = b
//parameter(6) = c

name_parameter(0)'ratio';

name_parameter(1)'Ploss_norm';
unit_parameter(1)'[W]';
```

```
name_parameter(2)'Nin_norm';
unit_parameter(2)'[rad/s]';

name_parameter(3)'Min_norm';
unit_parameter(3)'[Nm]';

name_parameter(4)'a';
name_parameter(5)'b';
name_parameter(6)'c';

//functions for output speed
neg_gate(1);                            //gate(1) is the output
f_gate(1)=parameter(0)*f_gate(0);

//xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
//functions for the input torque
P_out= f_gate(1)*e_gate(1); //W
N_in = f_gate(0);           //rad/s

Ploss_norm = parameter(1);
Nin_norm   = parameter(2);
Mi_norm    = parameter(3);   //do not use Min_norm. This gives
Pin_norm   = parameter(4);   //parser error: ( expected
                             //is bug because min is a function
aa = parameter(5); //0.4
bb = parameter(6); //0.4
cc = parameter(7); //0.2

M_in = ((P_out/Ploss_norm) + (cc*N_in/Nin_norm)) /
((N_in/Ploss_norm) - (aa*N_in/Pin_norm) - (bb/Mi_norm));

e_gate(0) = M_in;
```

See apparatus *gear* in *ges\examples\gear.mod*.

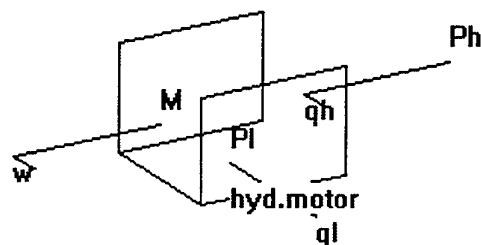For a another combination of input variables you must rewrite the equations.

3.4 Hydraulic library

The hydraulic library consist of four groups.

- **Pump** is an entry to a variable hydraulic motor and generator
- **Pipe resistance lambda** is a general pipe resistance
- **Pipe resistance Re** is for Reynolds < 2300
- **Pipe resistance CW** is for Reynolds > 2300.

3.4.1 Hydraulic-motor

gate	energy	input			output		
		variable	symbol	unit	variable	symbol	unit
0	pos	flow	qh	[m^3/s]	effort	Ph	[N/m^2]
1	neg	effort	Pl	[N/m^2]	flow	ω	[rad/s]
2	neg	effort	M	[Nm]	flow	ql	[m^3/s]

Table 19   Gate variables *hydraulic-motor*

qh is the driving flow in the high pressure pipe.
ql is the return flow in the low pressure pipe.
ω is the motor speed.
M is the motor torque.
Ph is the pressure in the high pressure pipe.
Pl is the pressure in the low pressure pipe.

Because P = Ph-Pl, Q = qh the equations of the *hydraulic-motor* are:

$$
\begin{bmatrix} \omega \\ P \end{bmatrix} = \begin{bmatrix} \dfrac{1}{\alpha\, q0} & -\dfrac{Ys}{\alpha^2\, q0^2} \\ 0 & \dfrac{1}{\alpha\, q0} \end{bmatrix} \begin{bmatrix} Q \\ M + M0 \end{bmatrix}
$$

The general hydraulic motor is adjustable with α.

Mo is the starting torque of the motor.

q0 is the transmission. Practically $q0 = Q_{max} / \omega_{max}$.

Ys is the flow conductance. This factor is depending on the leakage of the motor. A practical value is 3%. So a value for *Ys* is for instance Q_{max} 3% / P_{max}

Parameter(0):

       Is the transmission factor α.

Parameter(1):

       Is the transmission ratio *q0*.
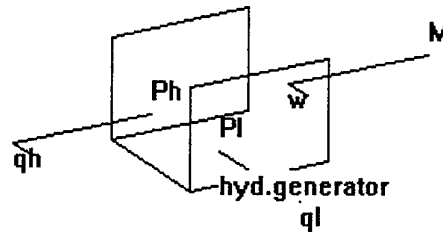
Parameter(2):

       Is the leak conductance *Ys*.

Parameter(3):

       Is the starting torque *M0*.

3.4.2 Hydraulic-generator

		input			output		
gate	energy	variable	symbol	unit	variable	symbol	unit
0	pos	flow	ω	[rad/s]	effort	M	[Nm]
1	neg	effort	Ph	[N/m^2]	flow	qh	[m^3/s]
2	neg	effort	Pl	[N/m^2]	flow	ql	[m^3/s]

Table 20   Gate variables *hydraulic-generator*

qh is delivery flow in the high pressure pipe.
ql is the source flow in the low pressure pipe.
ω is the generator speed.
M is the generator torque.
Ph is the pressure in the high pressure pipe.
Pl is the pressure in the low pressure pipe.

Because P = Ph-Pl, Q = qh the equations of the *hydraulic-generator* are:

$$\begin{bmatrix} Q \\ M \end{bmatrix} = \begin{bmatrix} \alpha\,q0 & -Ys \\ 0 & \alpha\,q0 \end{bmatrix} \begin{bmatrix} \omega \\ P \end{bmatrix} + \begin{bmatrix} 0 \\ M0 \end{bmatrix}$$

The general hydraulic generator is adjustable with α.
Mo is the starting torque of the generator (Coulomb resistance).
q0 is the transmission. Practically you can use $q0 = Q_{max} / \omega_{max}$.
Ys is the flow conductance. This factor is depending on the leakage of the generator. A practical value
is *3%*. So a value for Ys is for instance $Q_{max}\,3\% / P_{max}$
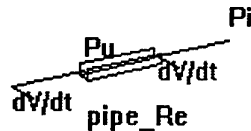
Parameter(0):
      The transmission factor α.
Parameter(1):
      The transmission ratio $q0$.
Parameter(2):
      The leak conductance Ys.
Parameter(3):
      The starting torque $M0$.

3.4.3 Pipe resistance lambda

gate	energy	input			output		
		variable	symbol	unit	variable	symbol	unit
0	pos	flow	dV/dt	[m^3/s]	effort	Pi	[N/m^2]
1	neg	effort	Pu	[N/m^2]	flow	dV/dt	[m^3/s]

Table 21   Gate variables *Pipe resistance lambda*

This apparatus can be used to described pipe resistance in the following form:
The usual expression for pipe resistance is:

$$\Delta P = \lambda \frac{1}{2} \frac{l}{d} \rho\, v^2$$

v is velocity of the liquid flow [m^3/s]
ρ is density [kg/m^3]
l is length of the pipe [m]
d is diameter of the pipe [m]
λ is resistance constant [-]

The resistance constant λ depends of the Reynolds constant Re.
Re is defined as:

$$\text{Re} = \frac{\rho\, d\, v}{\eta} \quad or \quad \text{Re} = \frac{d\, v}{\upsilon}$$

η = dynamic viscosity [Ns/m^2]
v = kinematic viscosity [m^2/s]

In GES the flow variable is expressed in m^3/s. The effort variable is the pressure ΔP. Then the effort variable is written as:
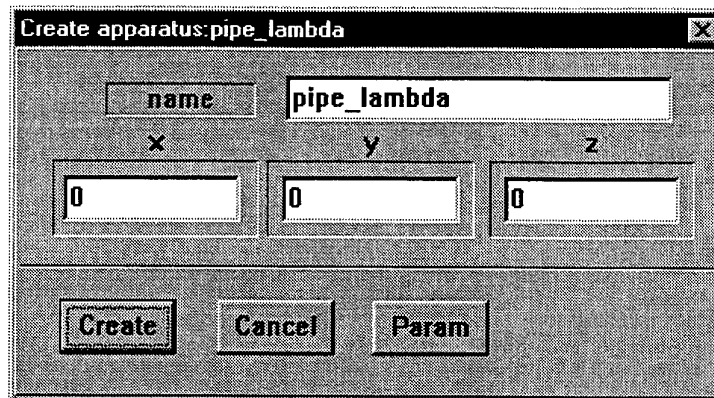
$$e = \frac{\lambda\, \rho\, l}{2\, d\, A^2} |f|\, f$$

To determine λ two area's must be discerned.
- laminar flow: Re < 2300
- turbulent flow: Re > 2300

For creating a pipe resistance the following dialog box is displayed.

If the apparatus is created, the following parameter values are displayed by clicking **Param**.